A systematic, regional approach to predictive modeling of habitat suitability for deep-sea corals in U.S. waters

NOAA Deep Sea Coral Research and Technology Program (DSCRTP) webinar series
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BRIAN P. KINLAN
Biogeography Branch
National Centers for Coastal Ocean Science (NCCOS)
NOAA National Ocean Service
Brian.Kinlan@noaa.gov

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National Ocean Service

Photo credit: NOAA DSCRTP 2012 Report to Congress

Key Collaborators/Data Providers

Matt Poti (NOAA NCCOS)
Laurie Bauer (NOAA NCCOS)
Martha Nizinski (NOAA NMFS OS&T NSL)
Peter Etnoyer (NOAA NCCOS)
Robert McGuinn (NOAA NCCOS)
Dan Dorfman (NOAA NCCOS)
Tom Hourigan (NOAA NMFS DSCRTP)
Dave Packer (NOAA NMFS NEFSC)
Tim Shank (WHOI)
Taylor Heyl (WHOI)
Dan Wagner (NOAA NCCOS)
Janessy Frometa (NOAA NCCOS)
Enrique Salgado (NOAA NCCOS)
Frank Parrish (NOAA NMFS PIFSC)
Eric Cordes (Temple University)
Chuck Fisher (Penn State University)
John Reed (HBOI)
Dave Stevenson (NOAA NMFS NERO)
Bryan Costa (NOAA NCCOS)
Chris Kelley (NOAA NMFS PIFSC)
Emma Hickerson (NOAA NOS FGBNMS)
Mark Mueller (BOEM)
Jeremy Potter (NOAA OAR OER)
Greg Boland (BOEM)
Anna Metaxas (Dalhousie University)
Peter Auster (University of Connecticut)
Peter Lawton (Canada DFO)
Chris Jenkins (Univ. of Colorado Boulder)
John Goff (UT Austin)
Bill Shedd (BOEM)
Cody Kramer (BOEM)
JD Dubick (NOAA NCCOS)
Sam Georgian (USGS)
Tim Battista (NOAA NCCOS)
Laughlin Siceloff (NOAA NCCOS)
Meme (Elizabeth) Lobecker (NOAA CCOM)

And many, many more involved in collection, archiving, processing, and analysis of oceanographic, environmental, and deep coral data, field model validation efforts, and management applications.

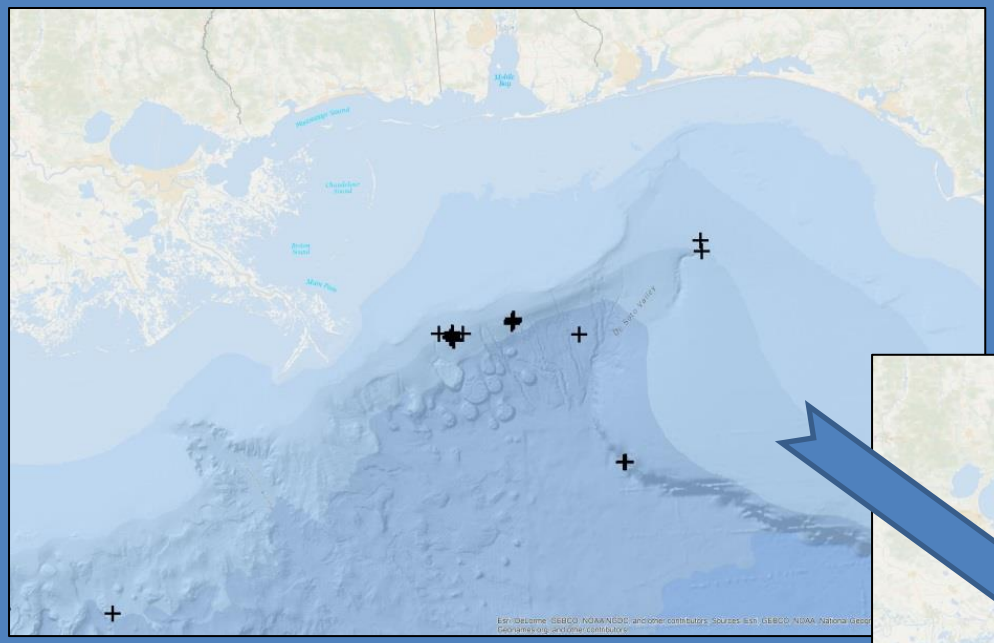
Deep-Sea Corals

- Diverse and valuable resource
- Important providers of habitat structure for fishes and invertebrates
- Conservation concern
  - slow growth rates
  - vulnerability to bottom disturbance
- Need for spatial information on deep-sea coral distribution
  - poorly explored
  - deep sea surveys are logistically difficult and expensive

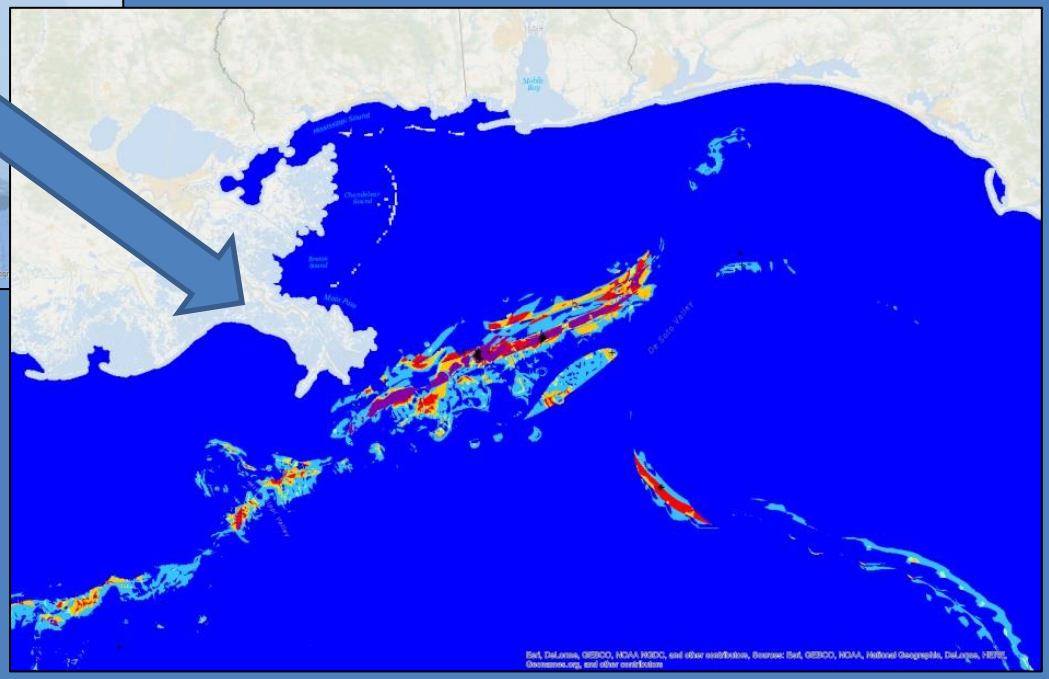
Conger eel and squat lobster in *Lophelia* reefs. Photo Credit: S. Ross et al.

Iridogorgia Photo Credit: NOAA OER 2012

Models are an Essential Tool for Spatial Planning & Management



Leiopathes presences



Leiopathes presences overlaid on model

Photo credit: NOAA OER

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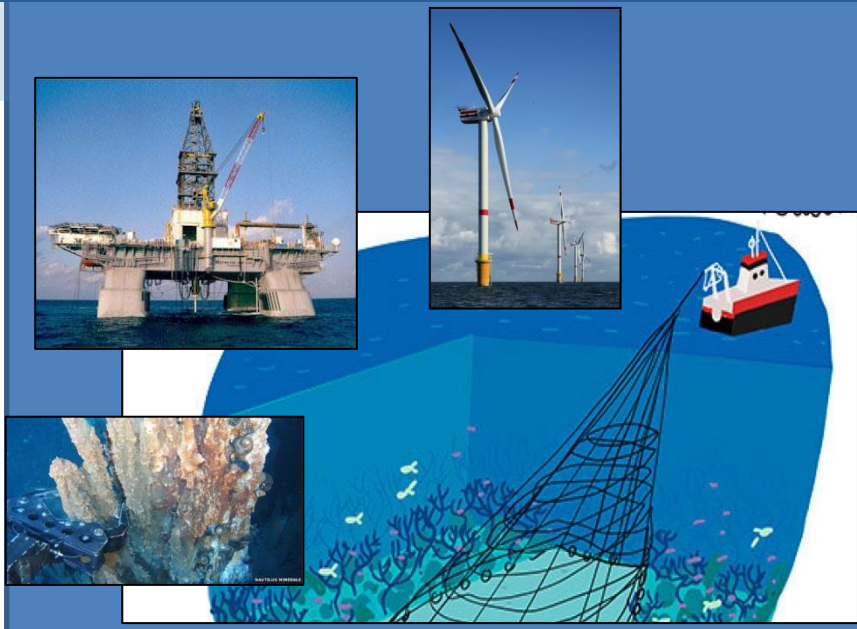
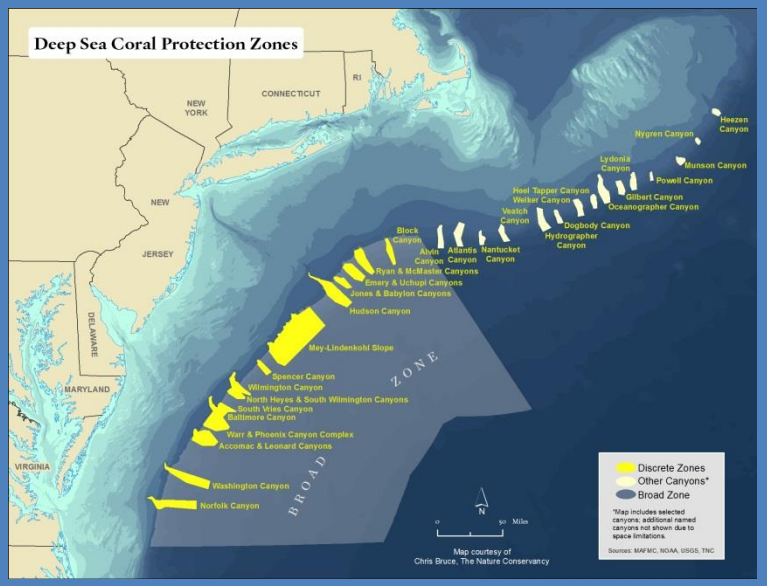
Value of Modeling

- Conservation planning
- Ecosystem-based fisheries management
- Siting and environmental impact assessment for offshore activities (e.g. ocean energy, mining)
- Damage assessment and restoration
- Targeting future mapping and exploration efforts
- Ecological studies





Outline

I. Methods & Data

II. Regional overview

III. Model validation

IV. Application stories

V. Next generation models

VI. Conclusion

Conger eel and squat lobster in *Lophelia* reefs. Photo Credit: S. Ross et al.

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Conger eel and squat lobster in *Lophelia* reefs.
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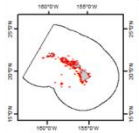
Deep-Sea Coral Habitat Suitability Modeling (Presence-only Models)

Step 1. Data preparation

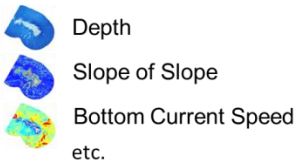
DSC presence data



Match data by location

+

Predictor grids



→ Combined data

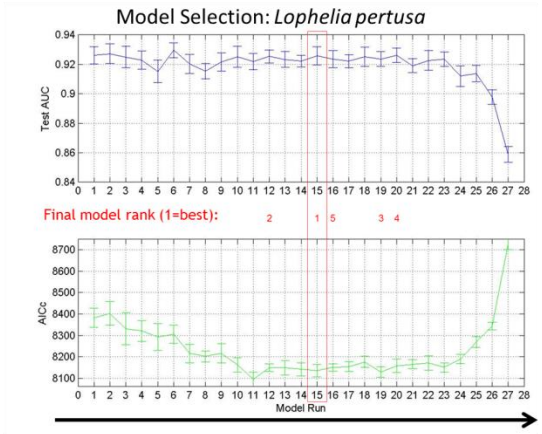
Step 2. Model fitting

Combined data → Create 10 random subsets (70% training/30% test) → Model fitting → Multiple models

Step 3. Model selection

Multiple models → Calculate test AUC, AICc → Rank models by highest test AUC & lowest AICc → Best model (best overall rank)

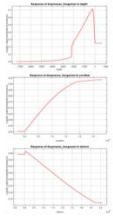
Drop least important predictor, repeat model fitting



Progressively simpler models (least important variable dropped on each successive model run)

Step 4. Prediction across space

Model functional relationships



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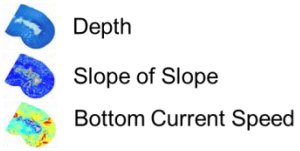
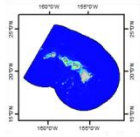
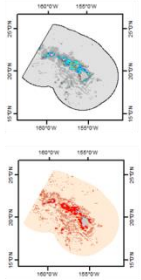
Predictor grids



→ Prediction → Predicted likelihood of suitable habitat (logistic output)



→ Classification applied

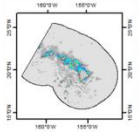


→ Predicted habitat suitability likelihood classes

→ Predicted habitat suitability uncertainty

Step 5. Model performance

Predicted habitat suitability likelihood classes



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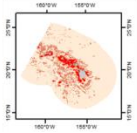
Prediction variability



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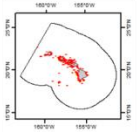
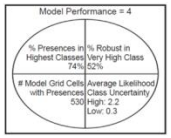
DSC presence data



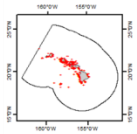
→ Performance metrics → Model performance badge



Data Preparation

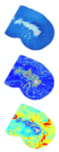
Step 1. Data preparation

DSC presence data



Match data by location +

Predictor grids



Depth

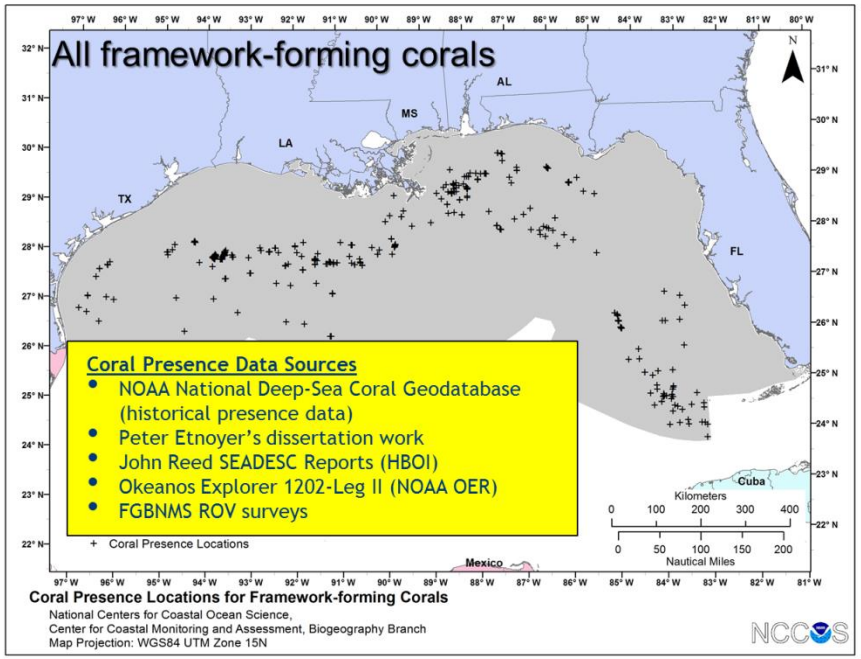
Slope of Slope

Bottom Current Speed

etc.

Combined data

Coral Presence Data



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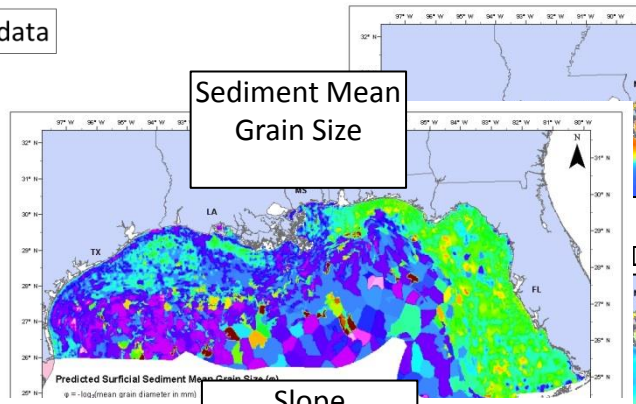
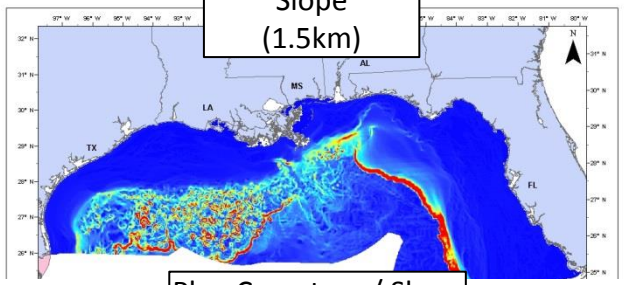
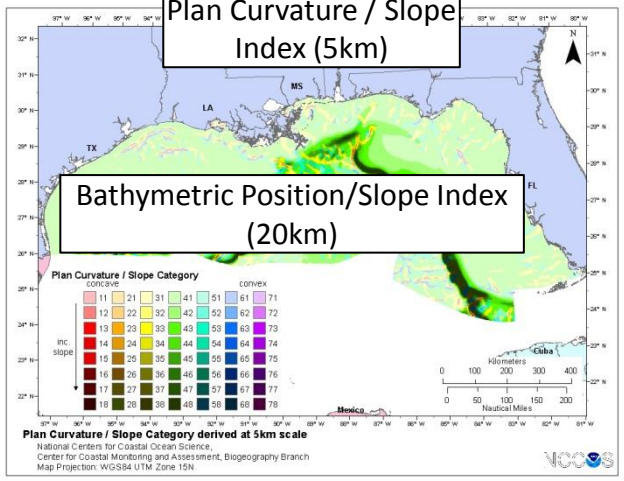
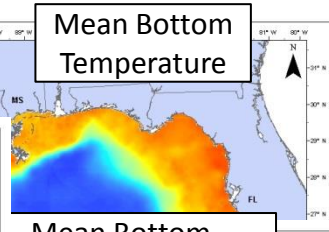
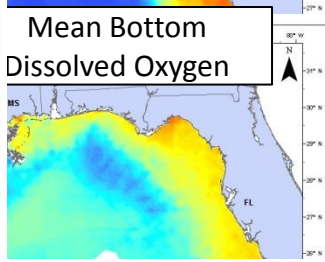
Environmental Predictor Data

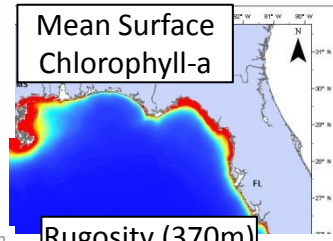


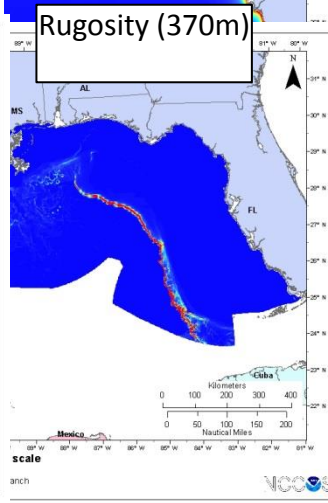








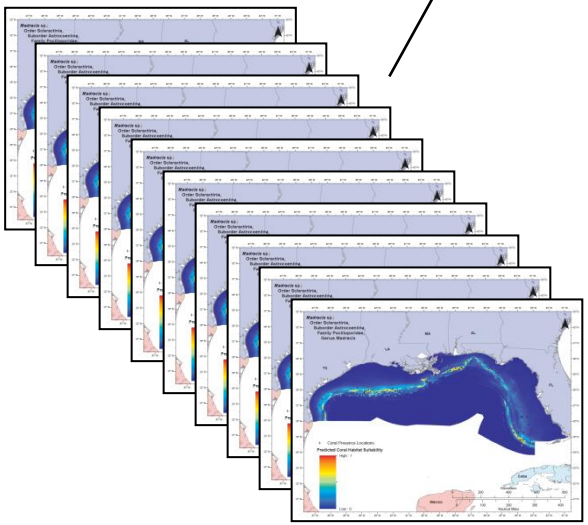




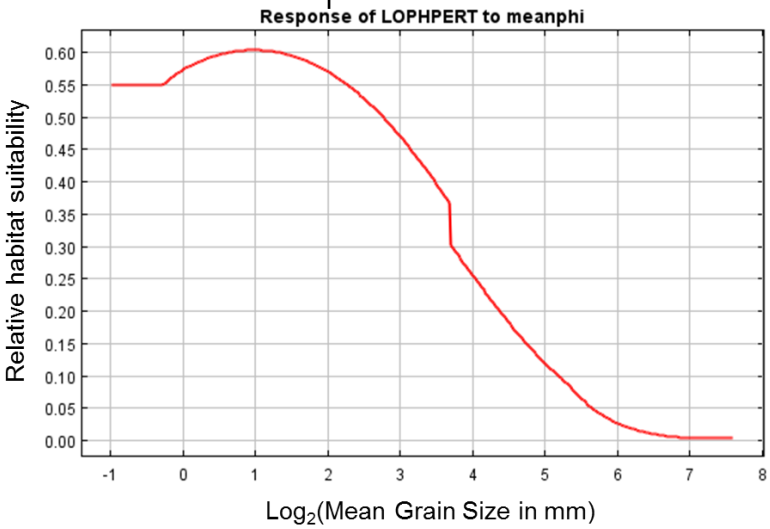
Model Fitting

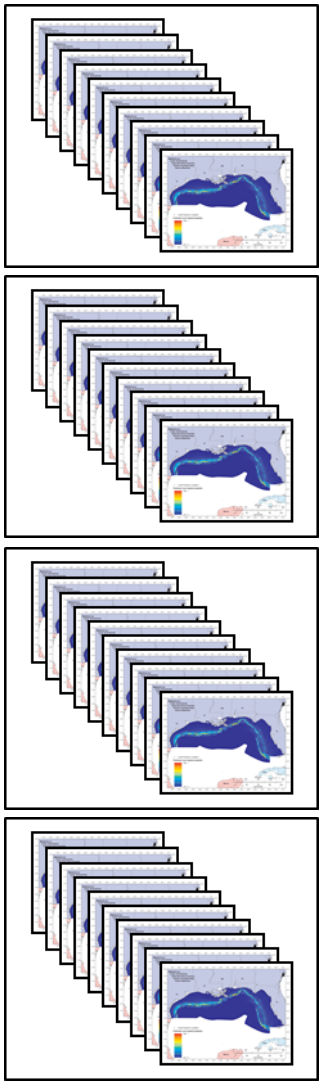
Step 2. Model fitting

Combined data → Create 10 random subsets (70% training/30% test) → Model fitting → Multiple models



MaxEnt version 3.3.3k
http://www.cs.princeton.edu/~schapire/maxent





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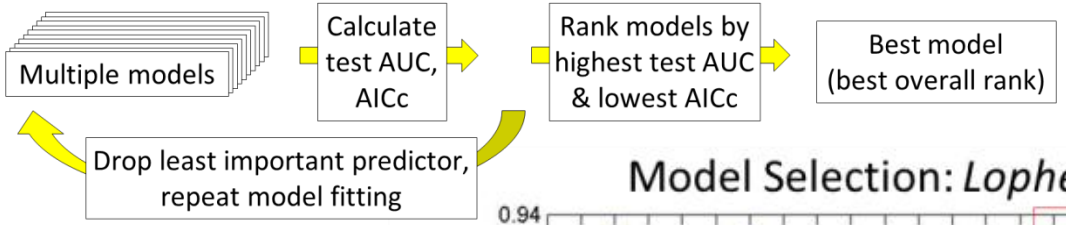
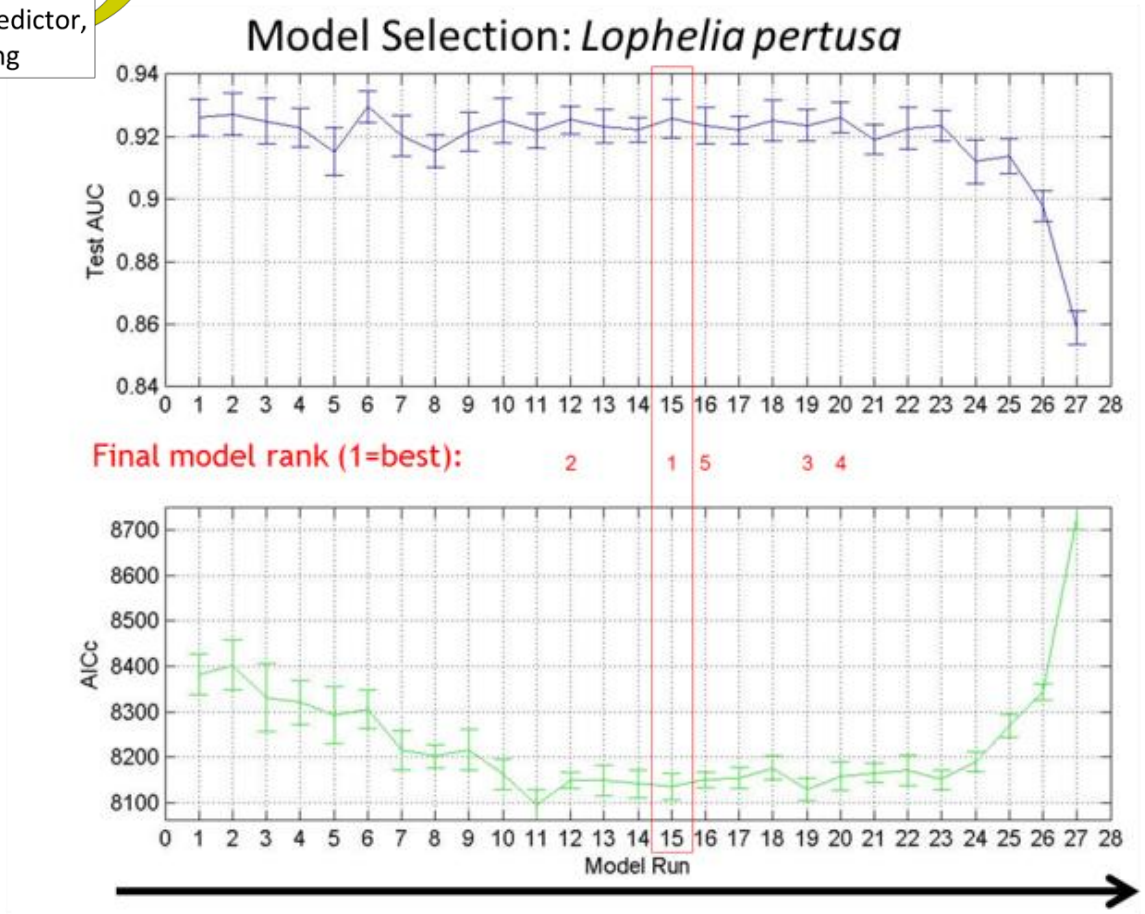
Model Selection

Step 3. Model selection



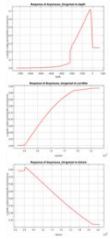


Progressively simpler models (least important variable dropped on each successive model run)

Spatial Predictions

Step 4. Prediction across space

Model functional relationships



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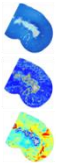
Predictor grids



Depth

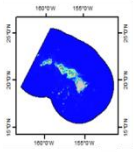
Slope of Slope

Bottom Current Speed

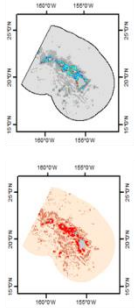
etc.

Prediction

Predicted likelihood of suitable habitat (logistic output)



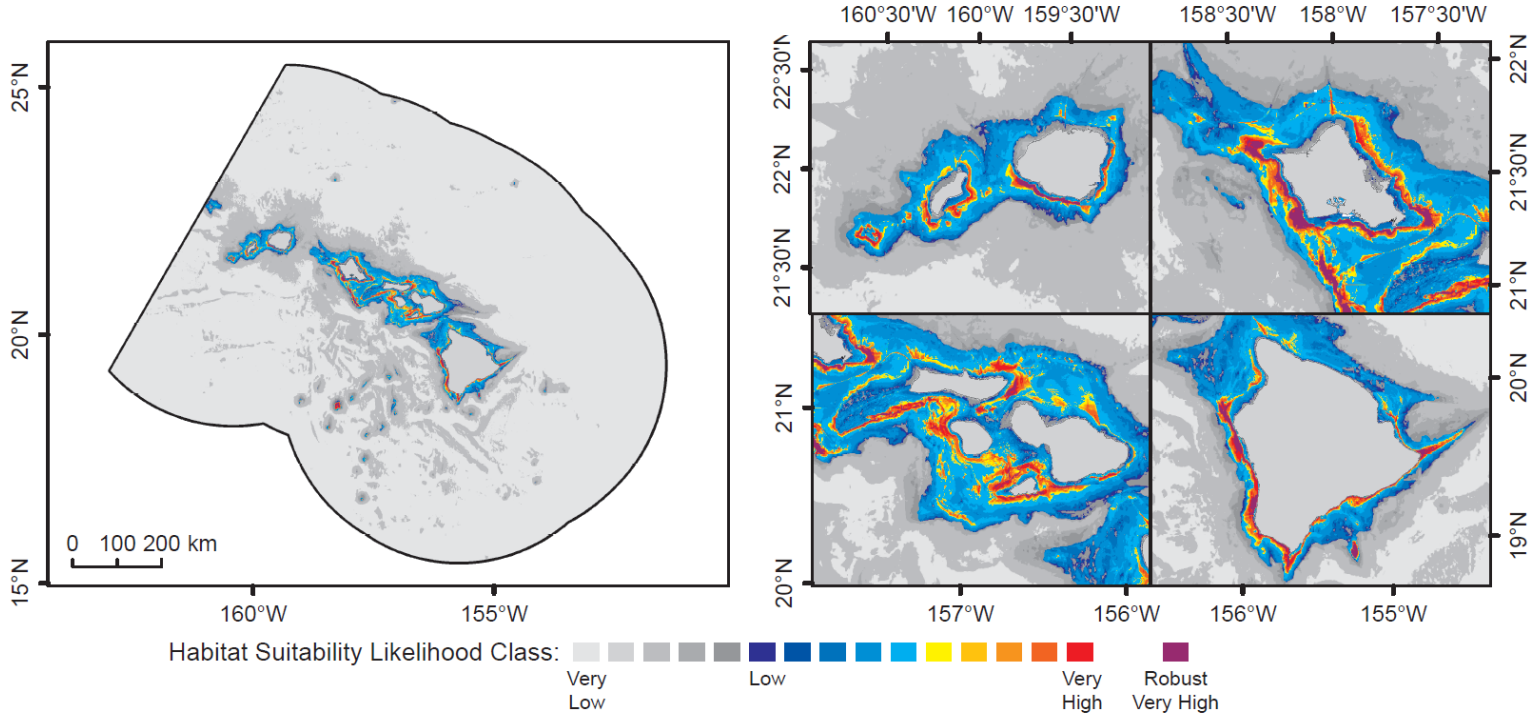
Classification applied



Predicted habitat suitability likelihood classes

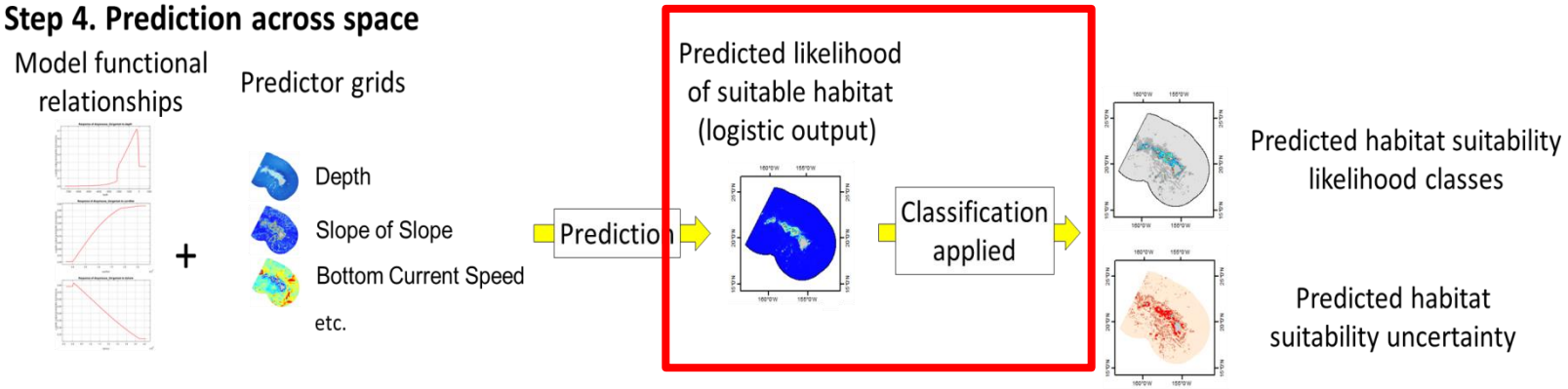
Predicted habitat suitability uncertainty

Gorgonian Alcyonacea Habitat Suitability Likelihood Classes

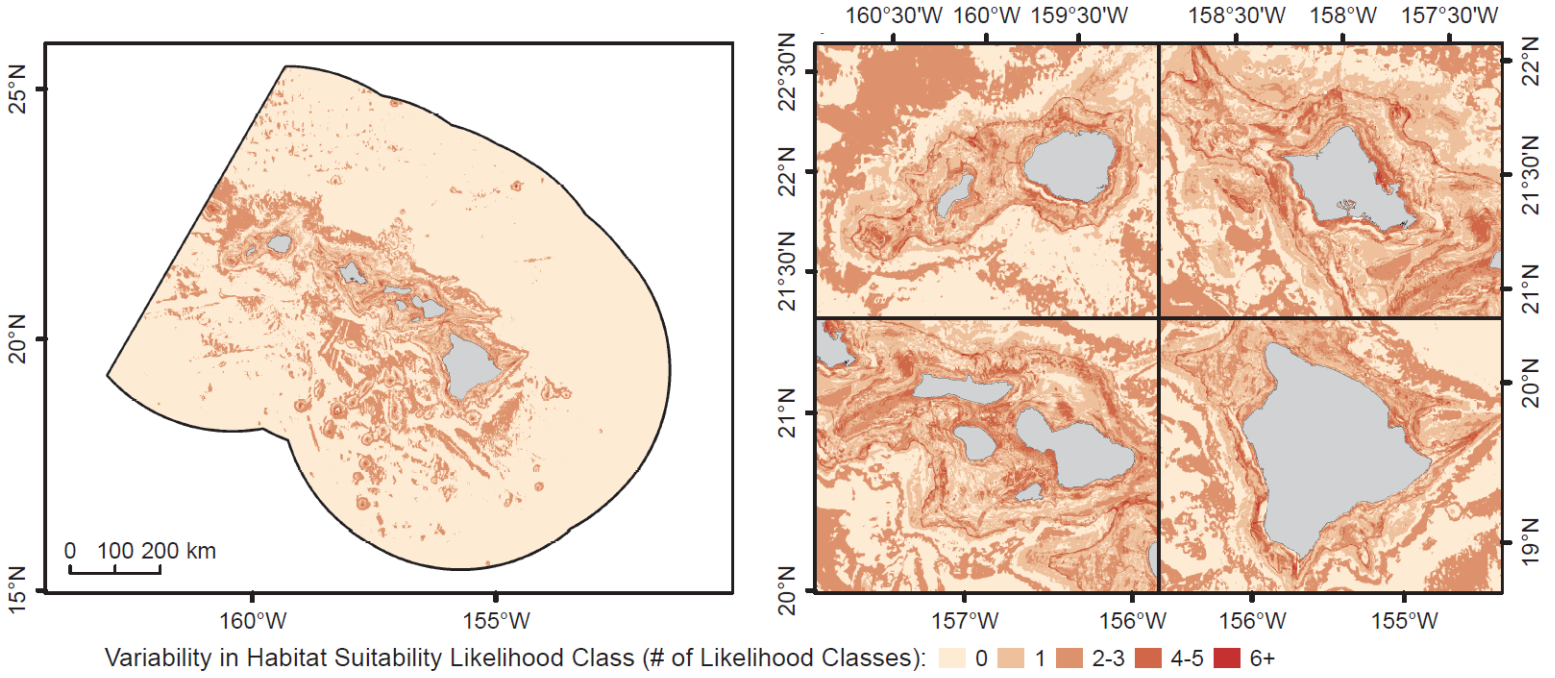


Spatial Predictions

Step 4. Prediction across space



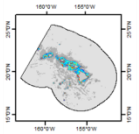
Gorgonian Alcyonacea Habitat Suitability Uncertainty



Model Accuracy & Performance Assessment

Step 5. Model performance

Predicted habitat suitability likelihood classes



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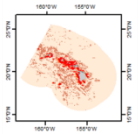
Prediction variability



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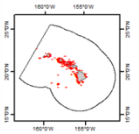


Performance metrics

Model performance badge

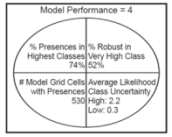
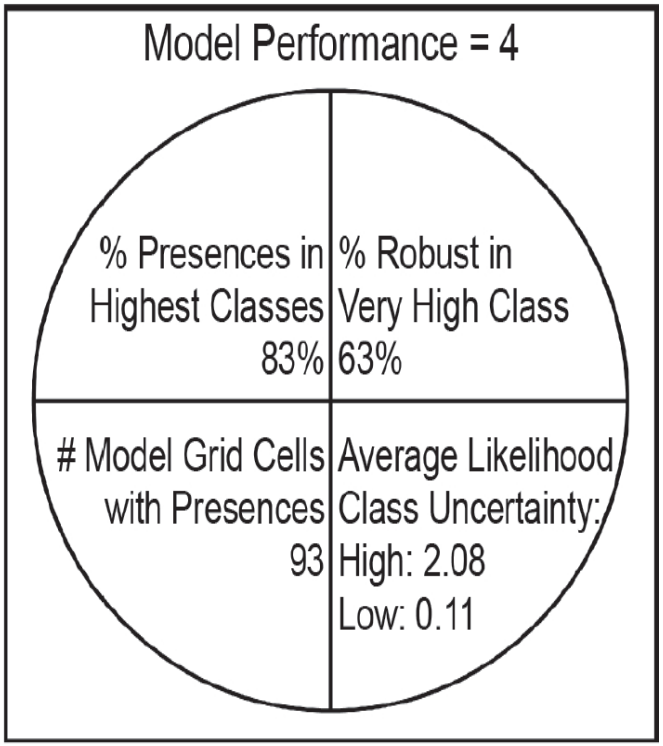


Table 3.10. Model performance metrics.

Name	Description	Stage	Quality Scores
Percent Presences in Highest Classes	Percentage of grid cells (with presence data) predicted to be in highest likelihood classes	Final model	5: >85% 4: 75–85% 3: 60–75% 2: 40–60% 1: <40%
Percent Robust in Very High Class	Percentage of grid cells predicted to be in the very highest likelihood class for all model runs	Model selection	5: > 55% 4: 45–55% 3: 35–45% 2: 25–35% 1: < 25%
# Model Grid Cells with Presences	Number of model grid cells containing presence data	Data preparation	5: >300 4: 150–300 3: 100–150 2: 50–100 1: <50
Average Likelihood Class Uncertainty	Average difference in likelihood classes (at 95% CI level) for all model runs	Model selection	5: <1 4: 1–1.5 3: 1.5–2 2: 2–3 1: >3



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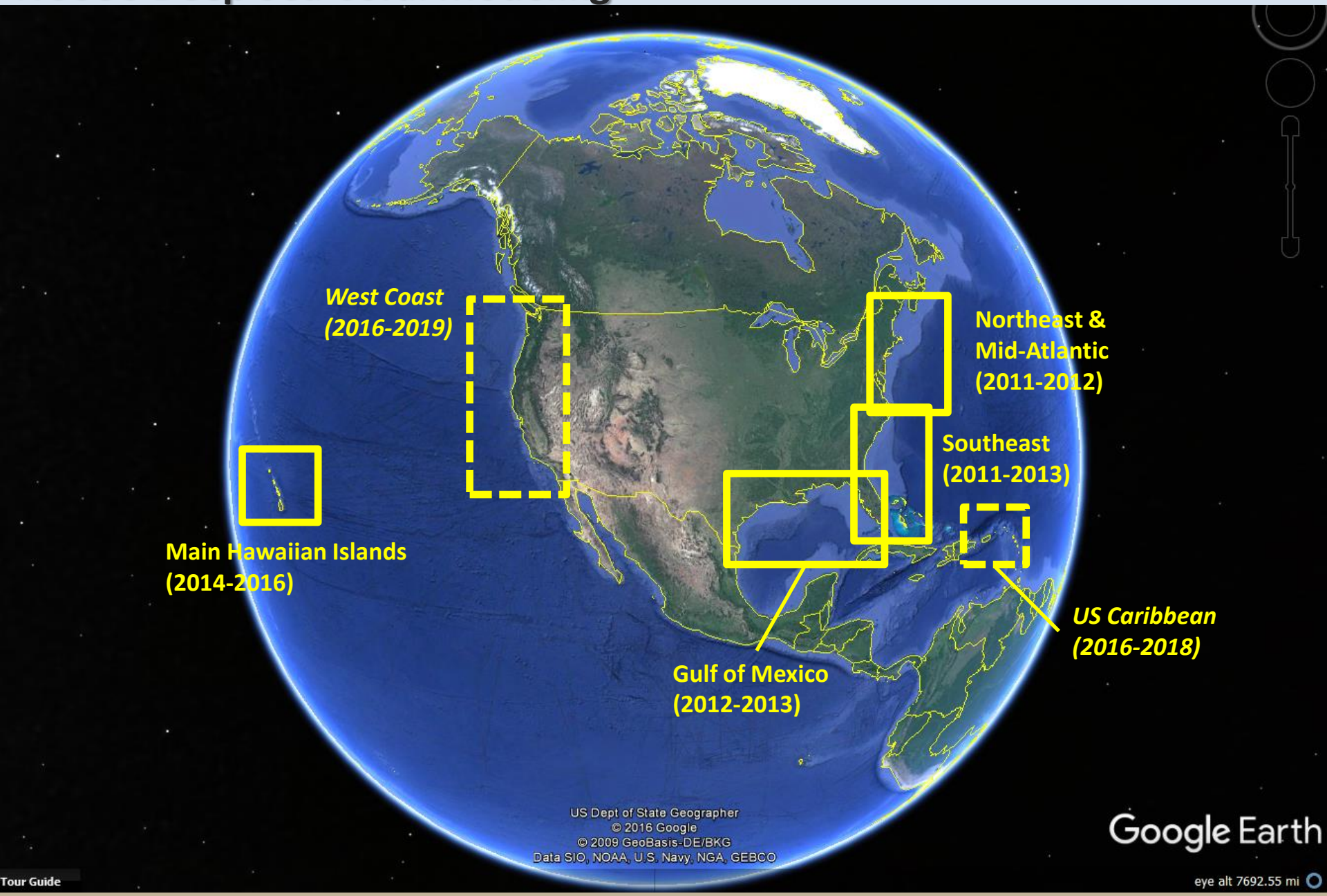
Conger eel and squat lobster in *Lophelia* reefs. Photo Credit: S. Ross et al.

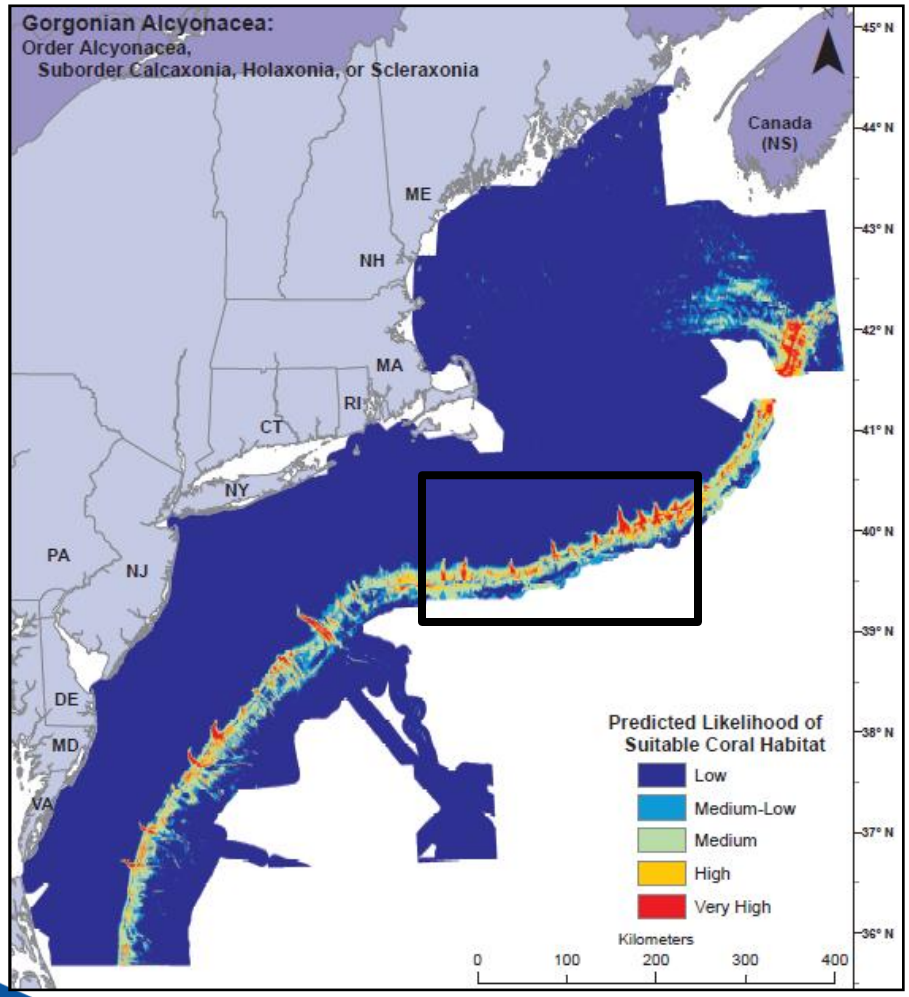
Iridogorgia Photo Credit: NOAA OER 2012

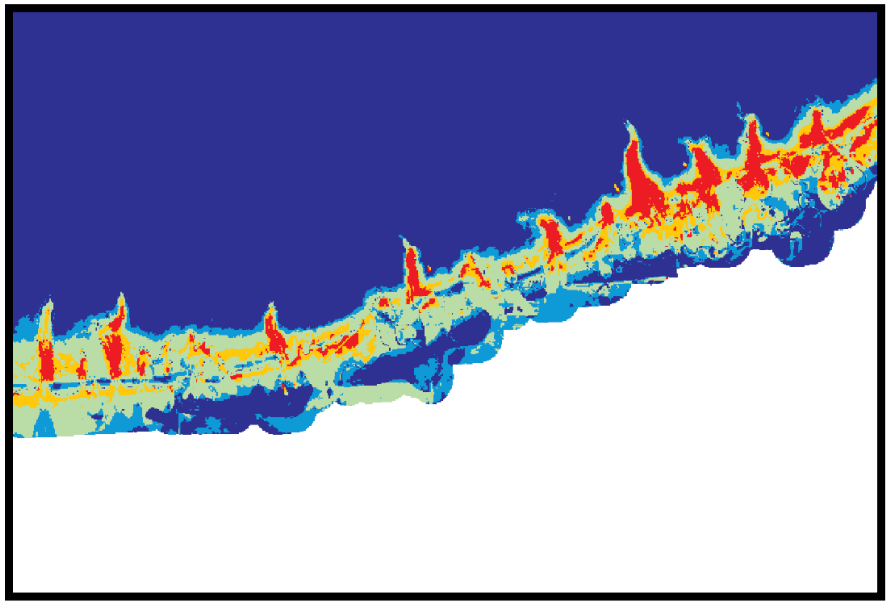
NCCOS Deep Sea Coral Modeling



Northeast & Mid-Atlantic

Key partners: Martha Nizinski (NEFSC, Nat'l Systematics Lab), Dave Packer (NEFSC), Tim Shank (WHOI), Taylor Heyl (WHOI), Peter Auster (U Conn.), Anna Metaxas (Dalhousie), Peter Lawton (Canada DFO), NOAA OER

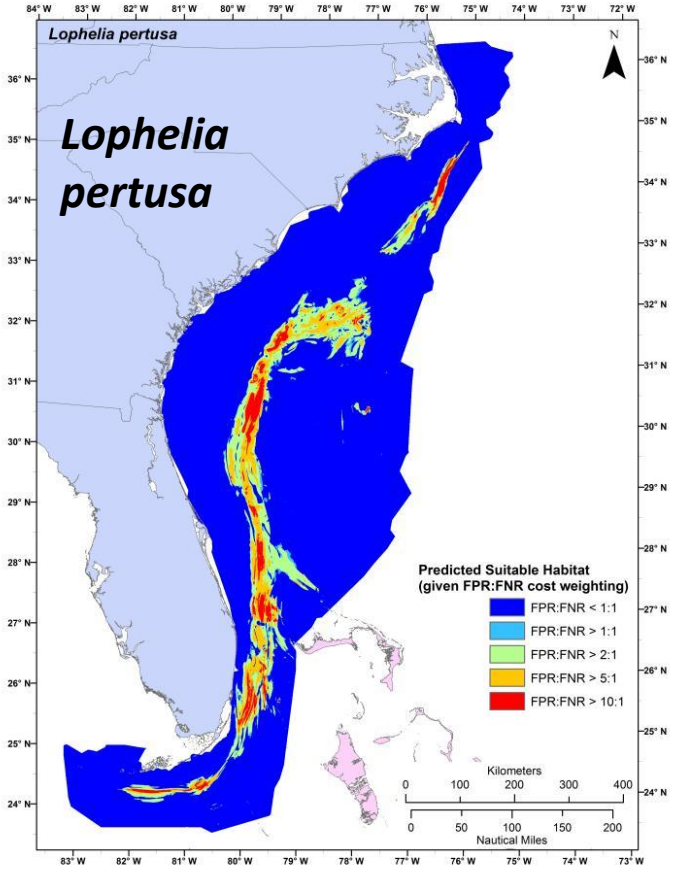


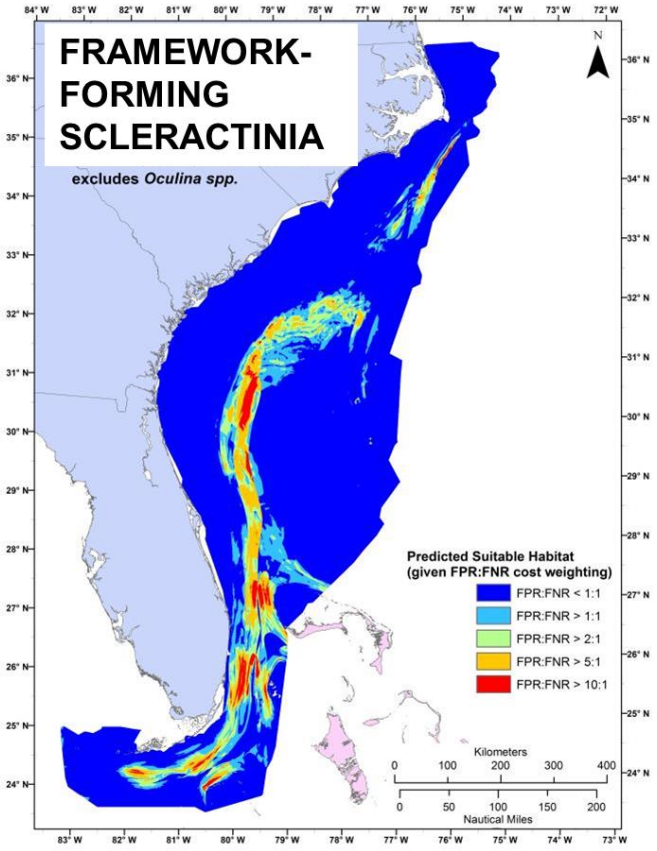


- Models created 2011-2012
- 9 coral groups
- 22 predictor variables

Southeast

Key partners: Tom Hourigan (DSCRTP), Andy David (SEFSC), John Reed (HBOI), Steve Ross (UNCW), USGS, BOEM

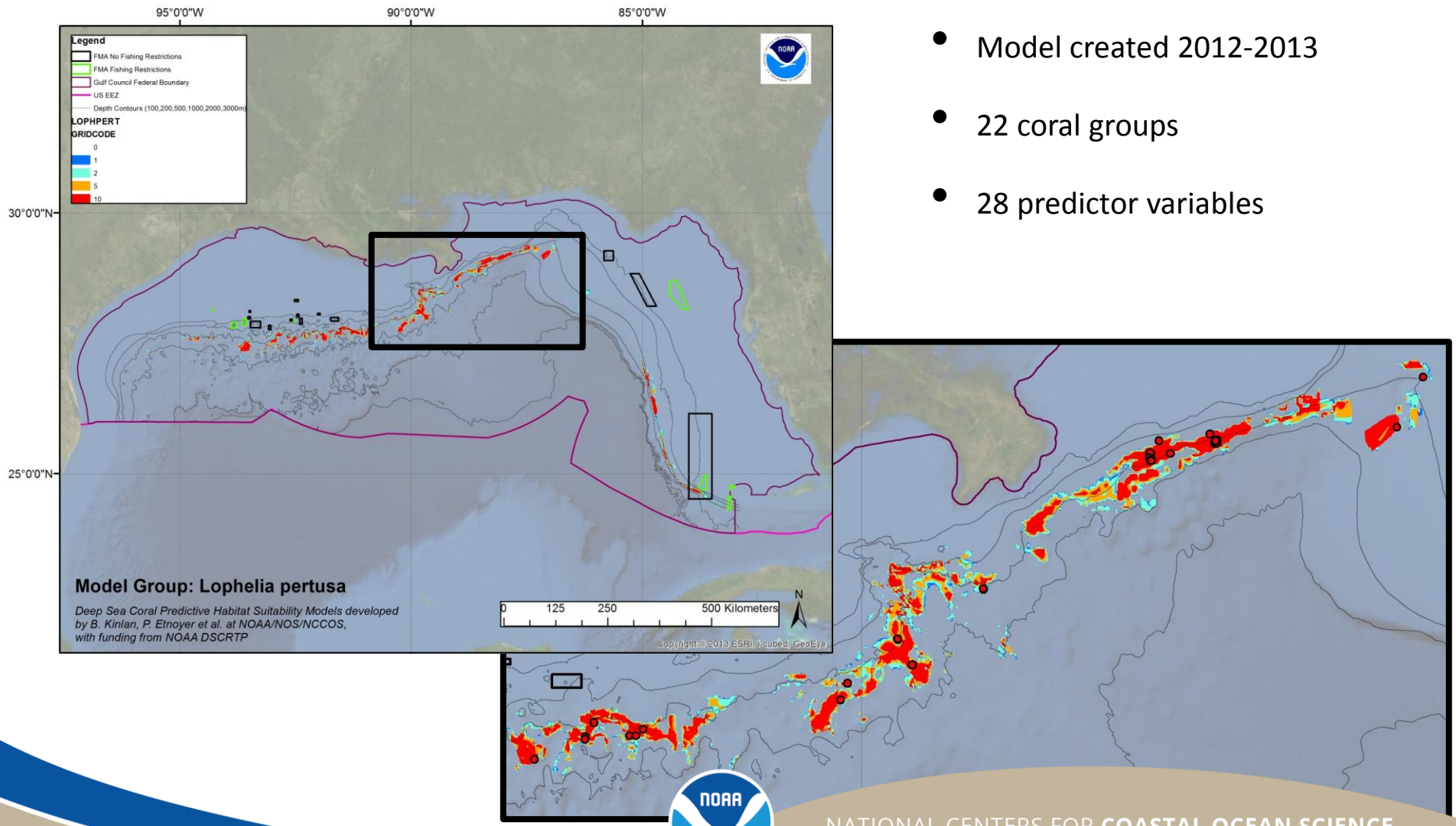




- Models created 2011-2013
- 14 coral groups
- 28 predictor variables

Gulf of Mexico

Key partners: Tom Hourigan (DSCRTP), Peter Etnoyer (NCCOS)



- Model created 2012-2013
- 22 coral groups
- 28 predictor variables

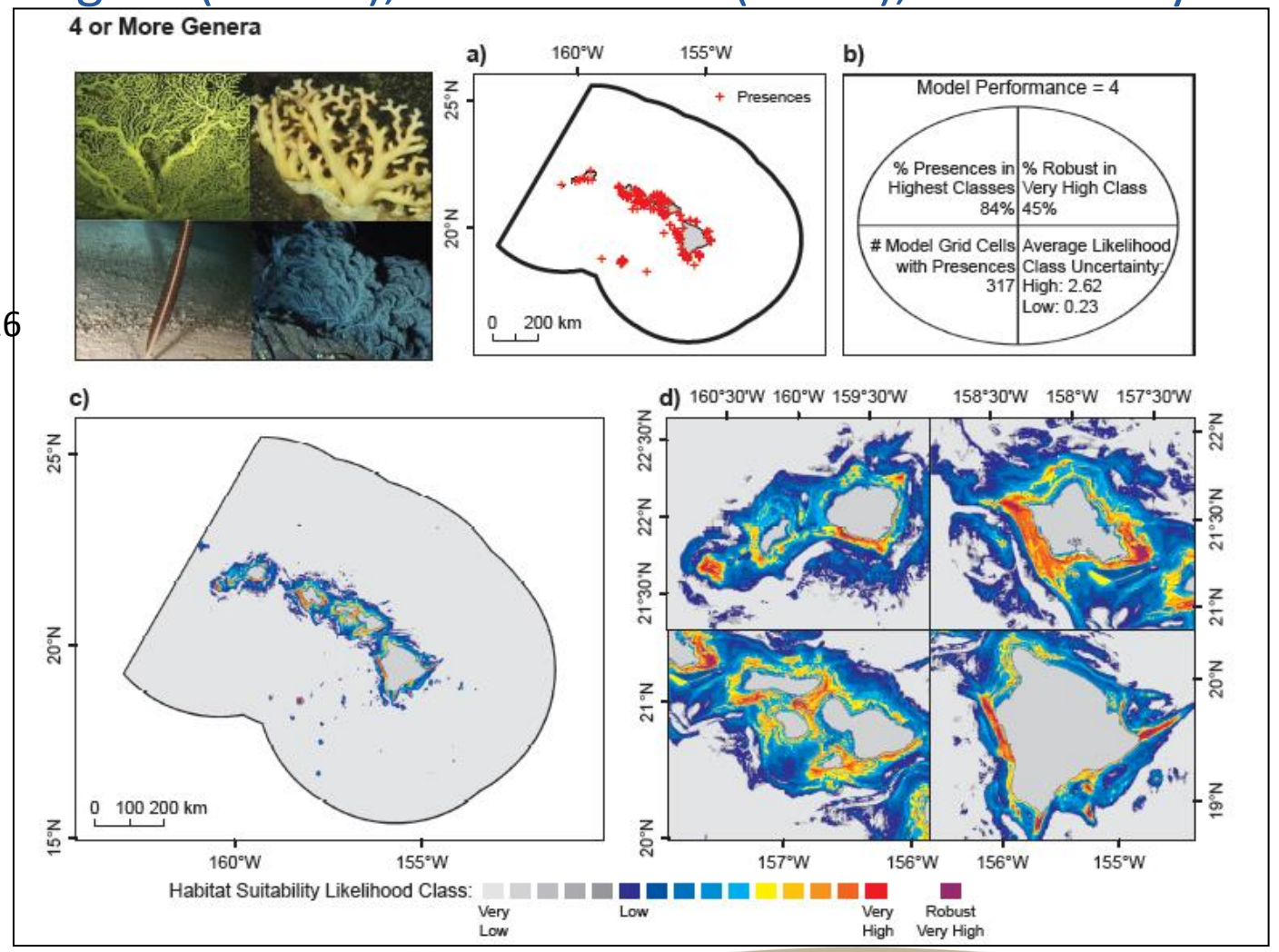
Gulf of Mexico – Predictor Variable Importance Summary

Type	Variable	%of groups for which variable selected
Seafloor topography	Depth	98%
Substrate	Interpreted 3D Seismic Anomalies	95%*
Seafloor topography	Slope of Slope (1500m)	55%
Substrate	Surficial Sediment Percent Sand	52%
Biological Oceanography	Annual Surface Chlorophyll-a	50%
Substrate	Surficial Sediment Mean Grain Size	50%
Seafloor topography	Rugosity (370m)	50%
Seafloor topography	Slope of Slope (5km)	43%
Physical Oceanography	Annual Bottom Salinity	40%
Physical Oceanography	Annual Bottom Temperature	38%
Seafloor topography	Profile Curvature / Slope Categories (20km)	38%
Seafloor topography	BPI/Slope Categories (20km)	33%

Main Hawaiian Islands

Key partners: Dan Wagner (ONMS), Frank Parrish (PIFSC), Chris Kelley (PIFSC), BOEM

- Models created 2014-2016
- 18 coral groups
- 39 predictor variables



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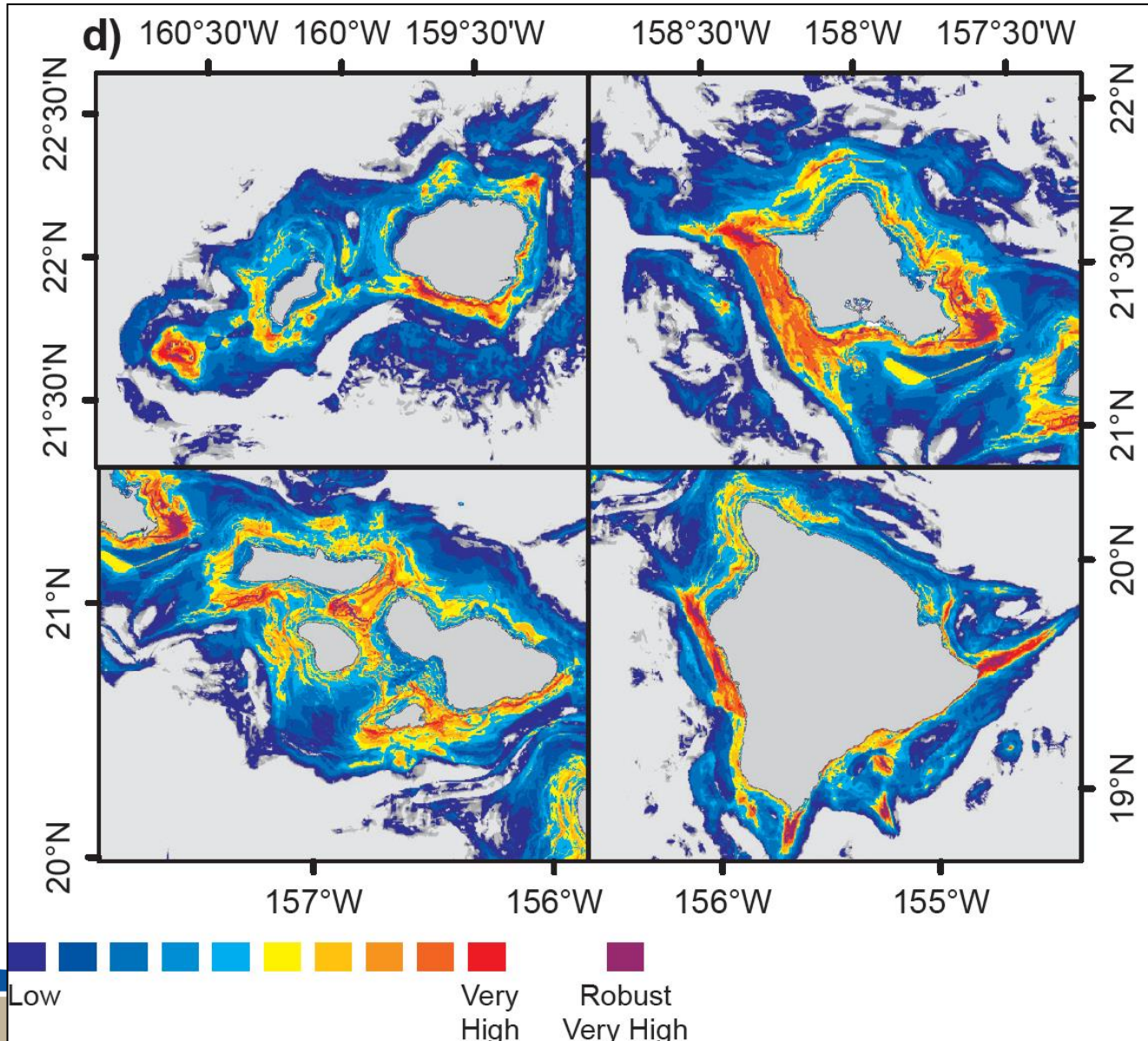
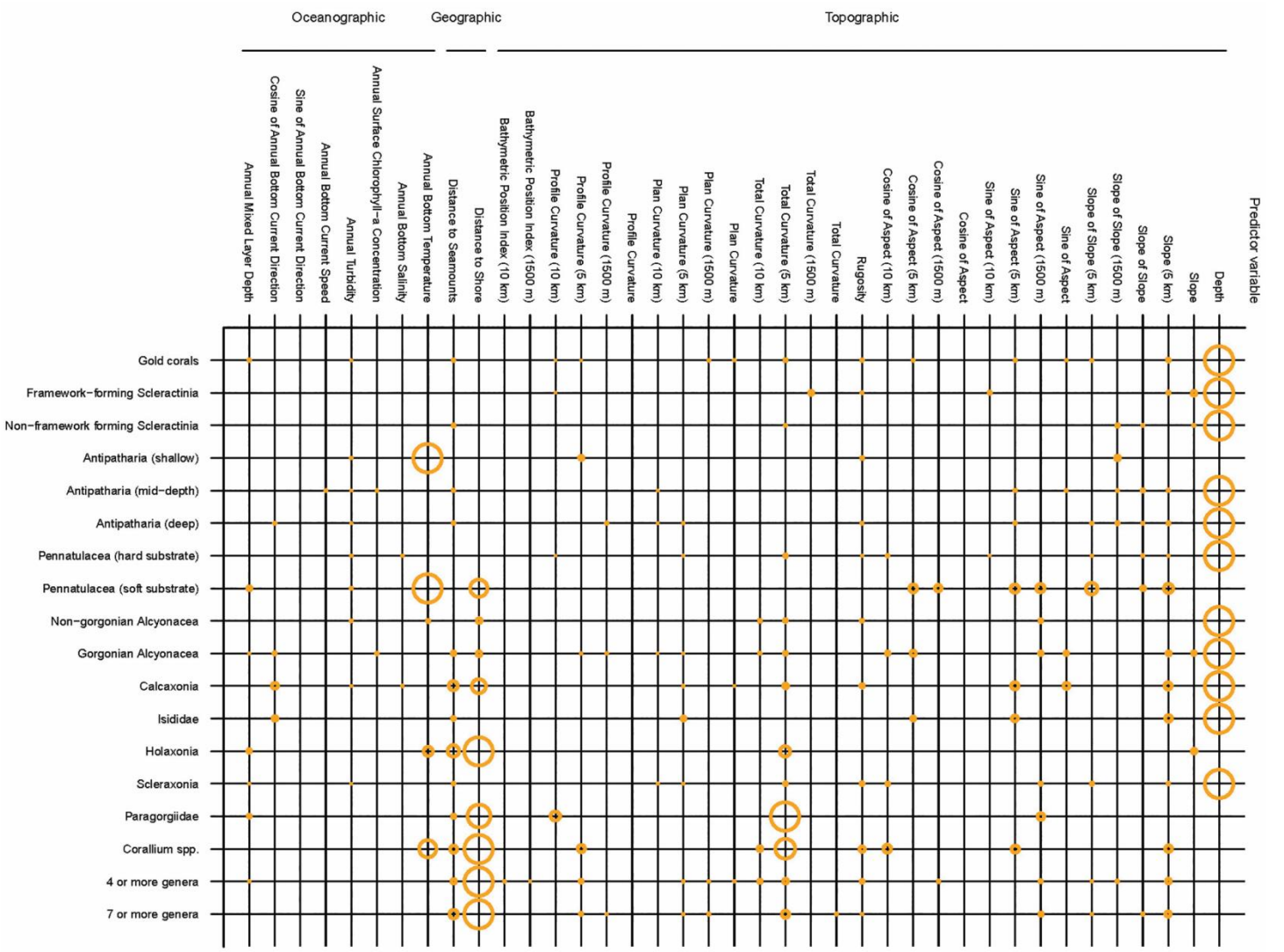
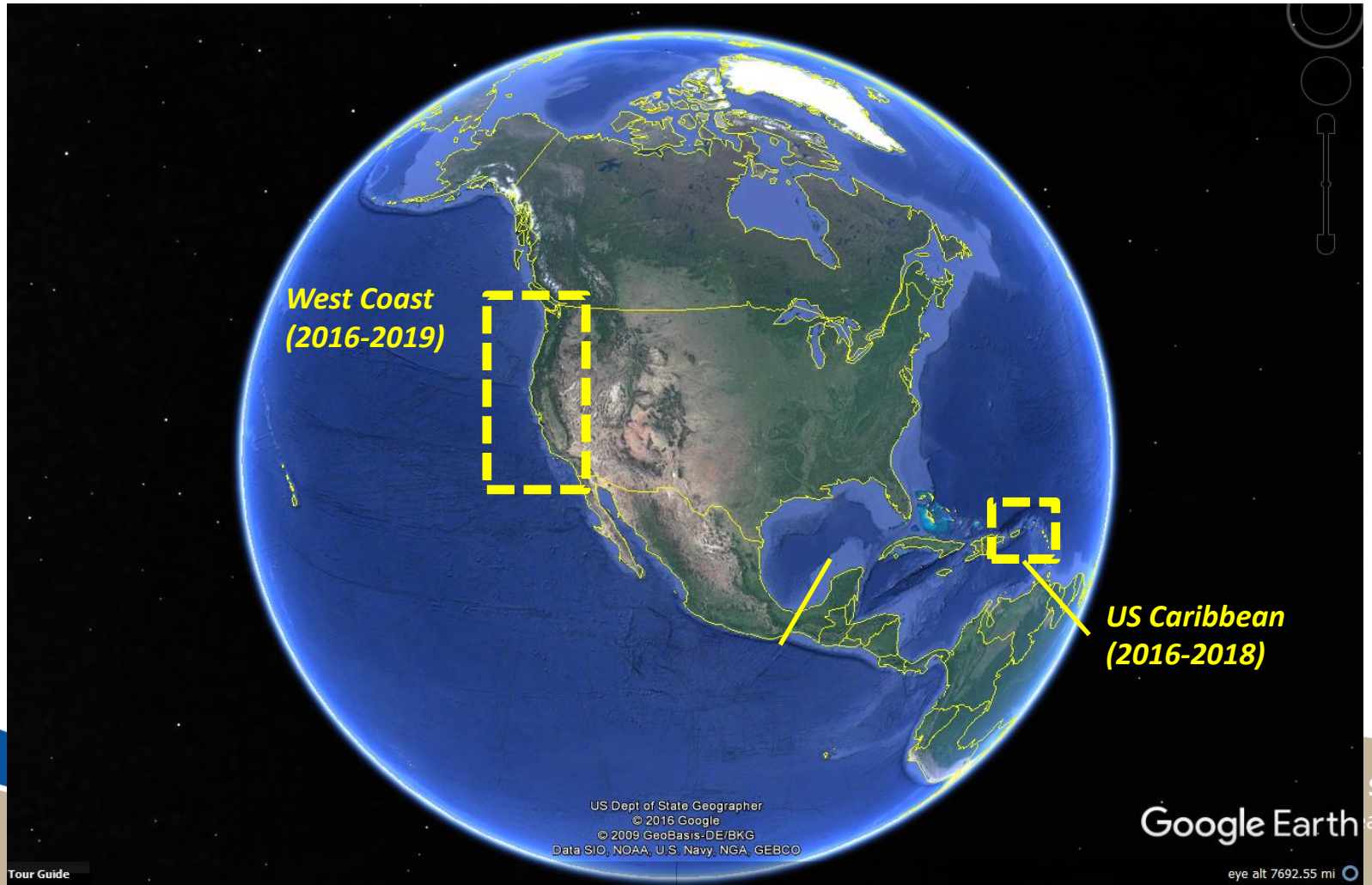


Main Hawaiian Islands – Predictor Variable Importance Summary

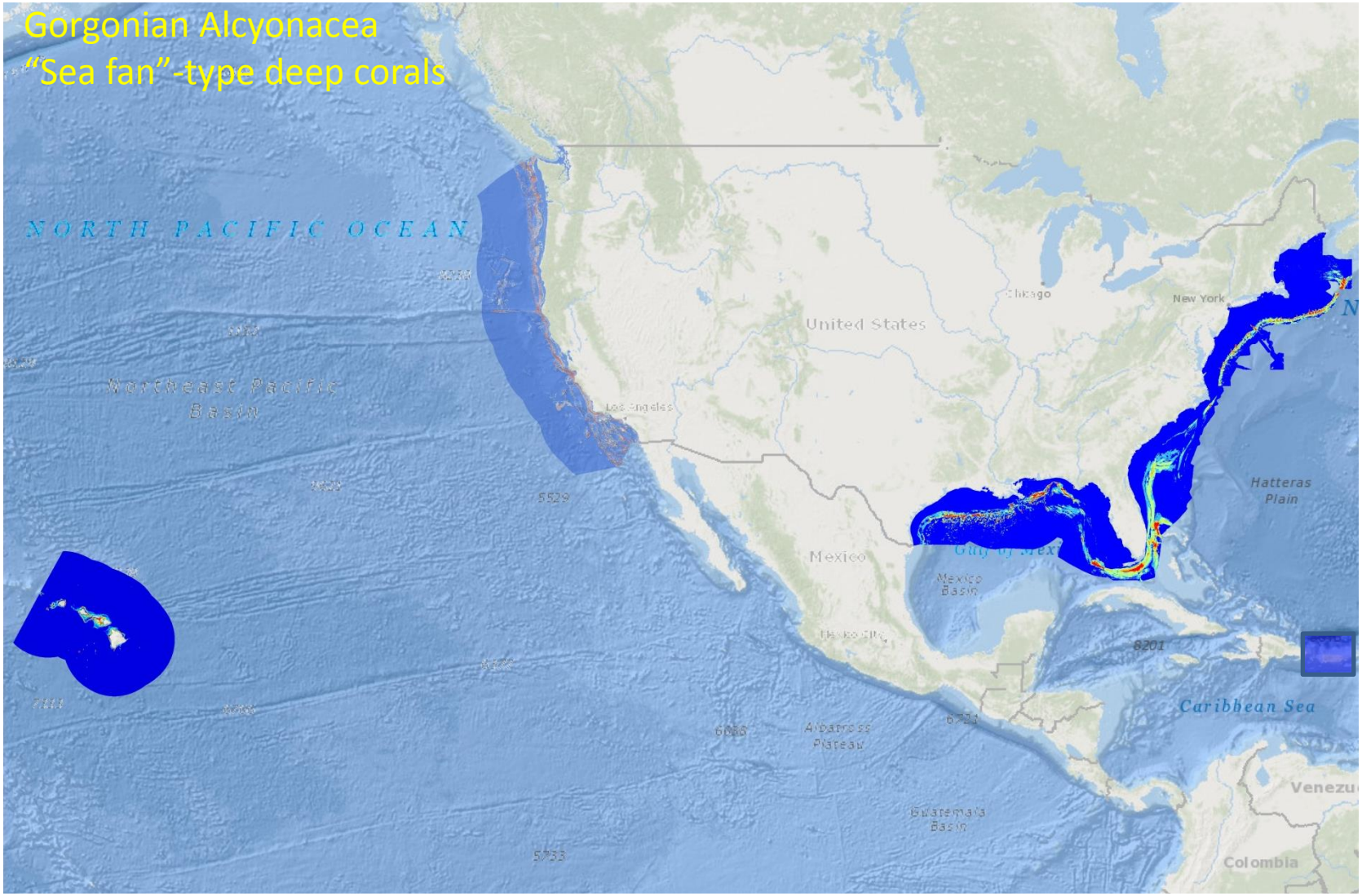


Upcoming Regions: West Coast & US Caribbean

Key partners: Mary Yoklavich (SWFSC), Liz Clarke (NWFSC), Curt Whitmire (NWFSC), Peter Etnoyer (NCCOS), Dan Wagner (NCCOS), Tim Battista (NCCOS), NOAA OER, BOEM



NCCOS Deep Sea Coral Modeling



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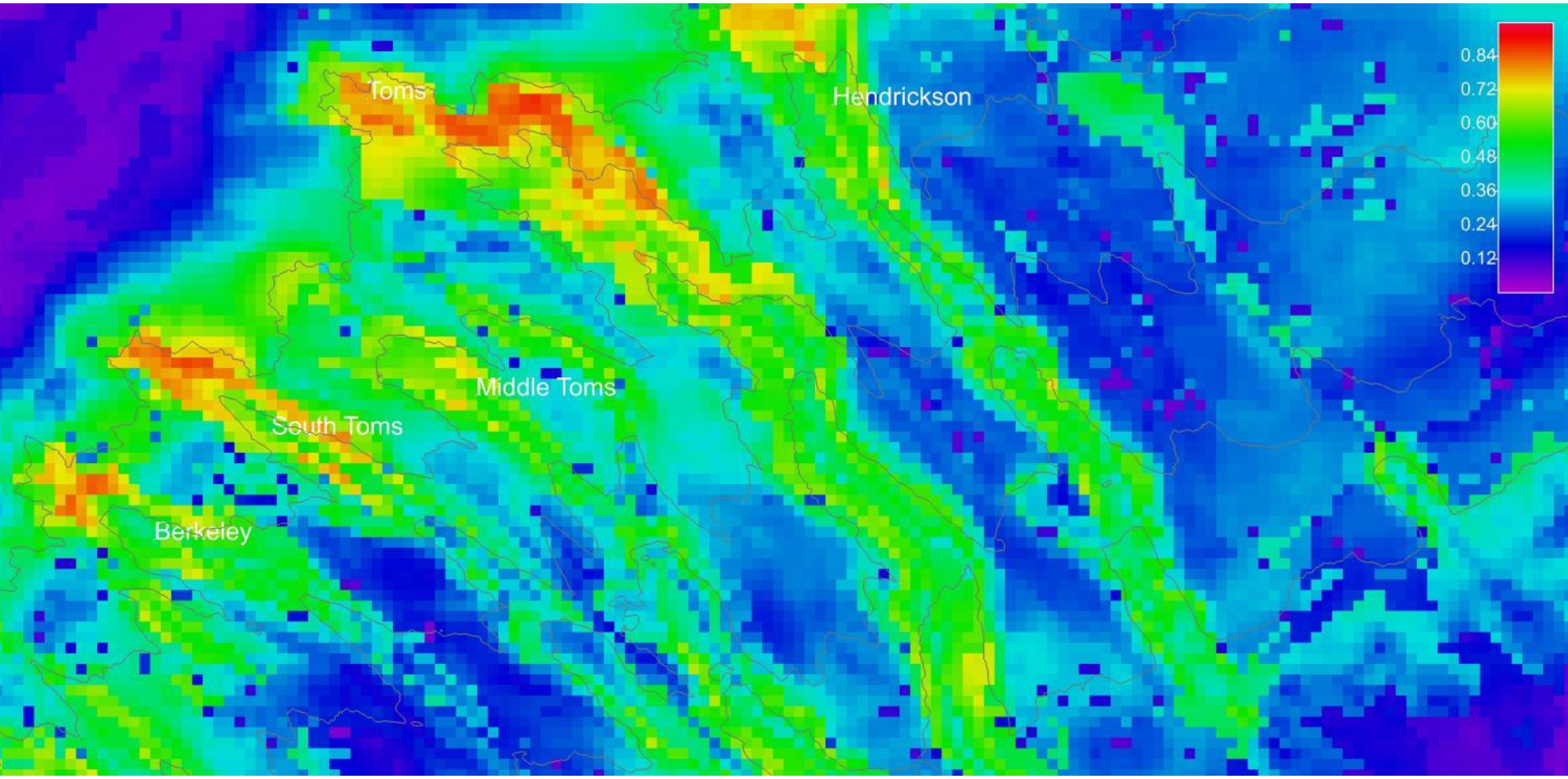
Conger eel and squat lobster in *Lophelia* reefs. Photo Credit: S. Ross et al.

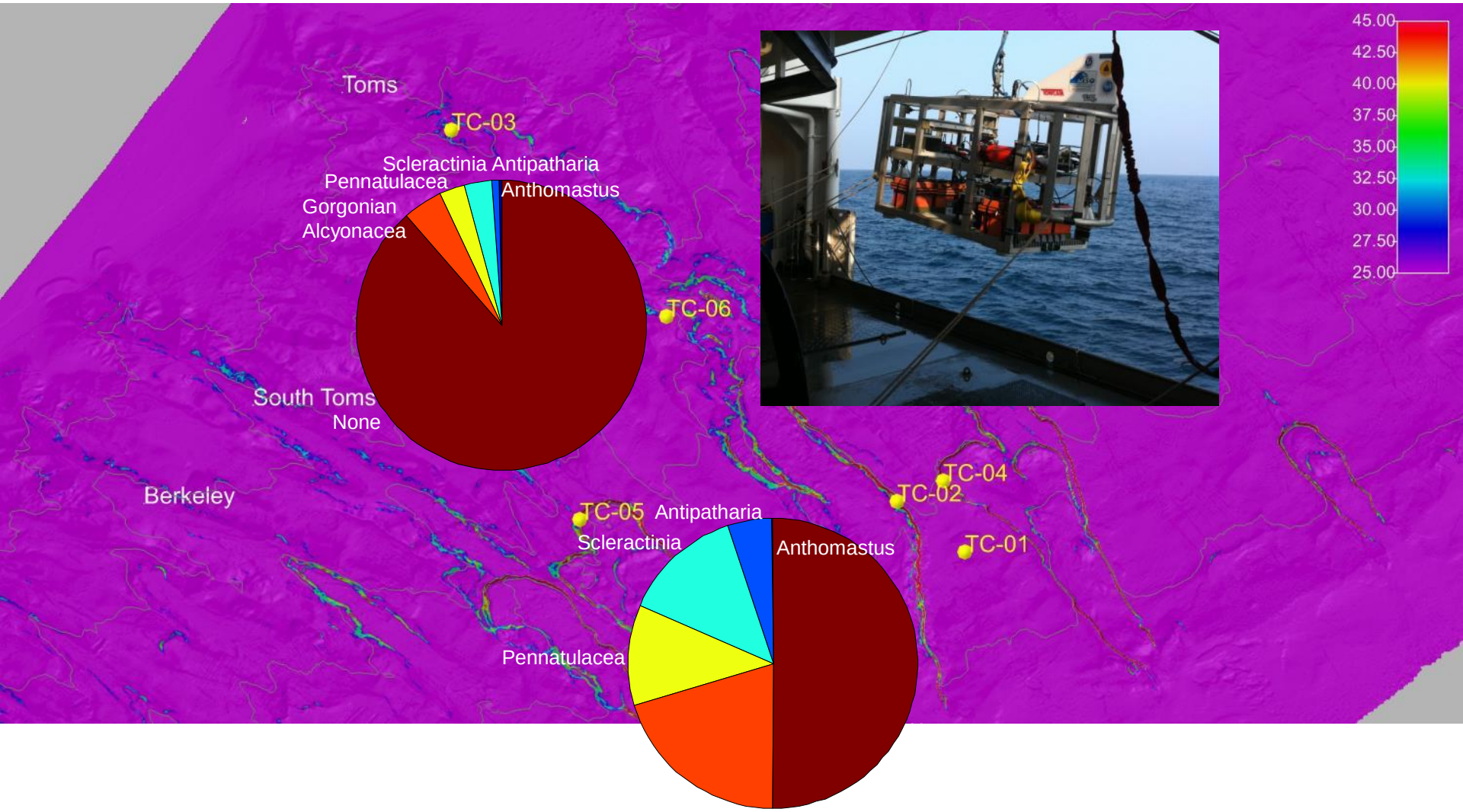
Iridogorgia Photo Credit: NOAA OER 2012

Northeast/Mid-Atlantic Model

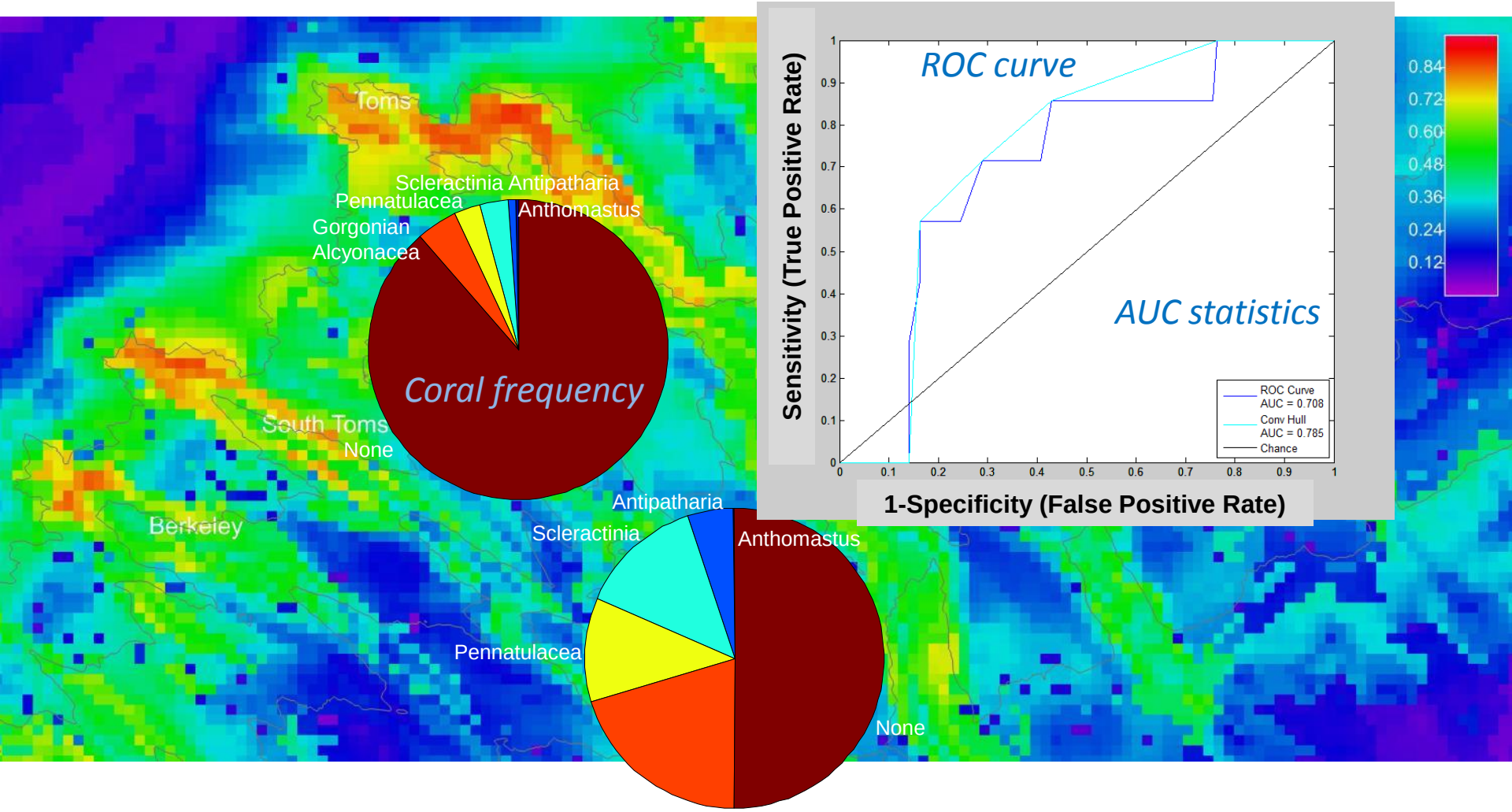
Example shown is for Gorgonian Alcyonacea



Sampling with WHOI TowCam and other remotely operated platforms



Information feeds back to validate and improve models.



Example ROC curve is for validation of Gorgonian Alcyonacea Model in the Northeast Region based on images from Tom's Canyon Complex, Ryan-McMaster Canyon Complex, Powell Canyon, and Veatch Canyon. An AUC value of 0.78 is at the upper end of the "Good" range based on commonly used qualitative descriptors of ROC analyses of model predictive power.

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Iridogorgia Photo Credit: NOAA OER 2012

Mid-Atlantic & New England Deep Coral Conservation Areas

The New York Times

Vote Aids Deep Sea Corals in Much of Mid-Atlantic

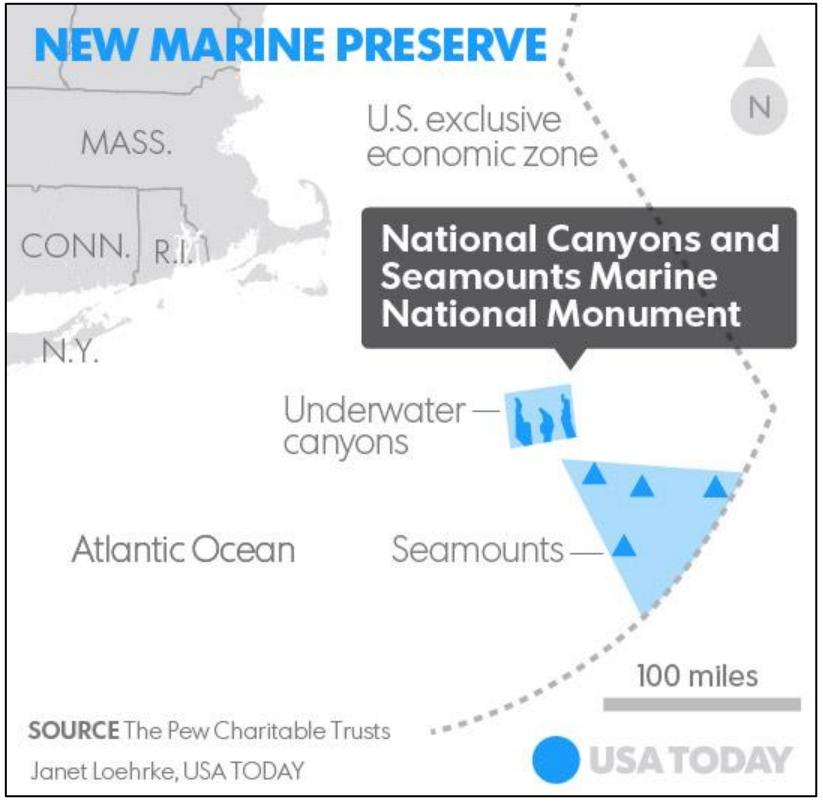
By JAMES GORMAN JUNE 10, 2015

The Mid-Atlantic Fishery Management Council voted Wednesday to protect deep sea corals from most bottom fishing over about 38,000 square miles of ocean, running from New York to Virginia.

The corals form fragile ecosystems hundreds of yards underwater that support a variety of fish. And bottom trawling, mostly by the squid fishery, posed a threat, according to scientists and conservation organizations that have lobbied in recent years to protect the corals, which are slow-growing and long-lived, and therefore do not recover easily from damage.

The squid industry, which initially objected to

Coral like these will be protected from most bottom fishing because of a Mid-Atlantic Fishery Management Council vote. National Oceanic and Atmospheric Administration



ce to applications

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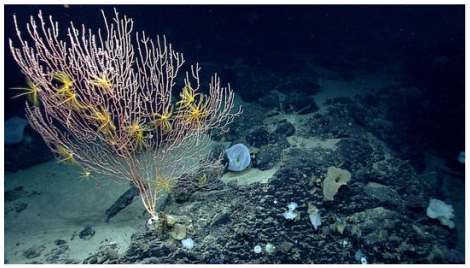
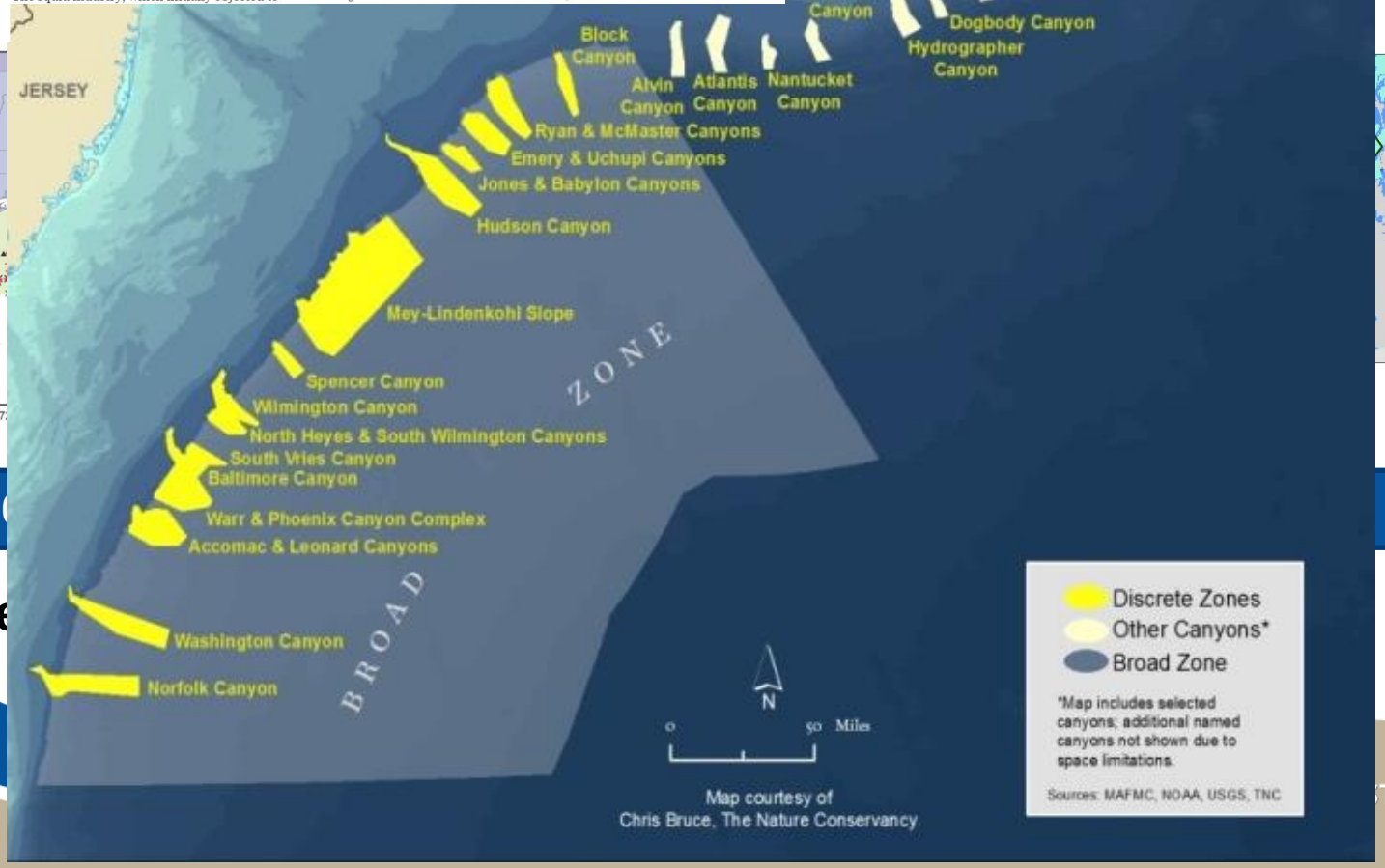
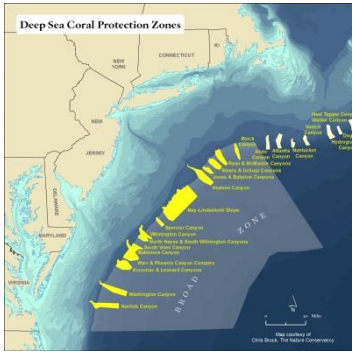


Coral like these will be protected from most bottom fishing because of a Mid-Atlantic Fishery Management Council vote. National Oceanic and Atmospheric Administration

Final Council Vote (June 10, 2015) ***[MAFMC]***





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2015

Re

Outcome

Northeast and Mid-Atlantic Regional Ocean Planning

NORTHEAST OCEAN PLAN

NORTHEAST REGIONAL PLANNING BODY

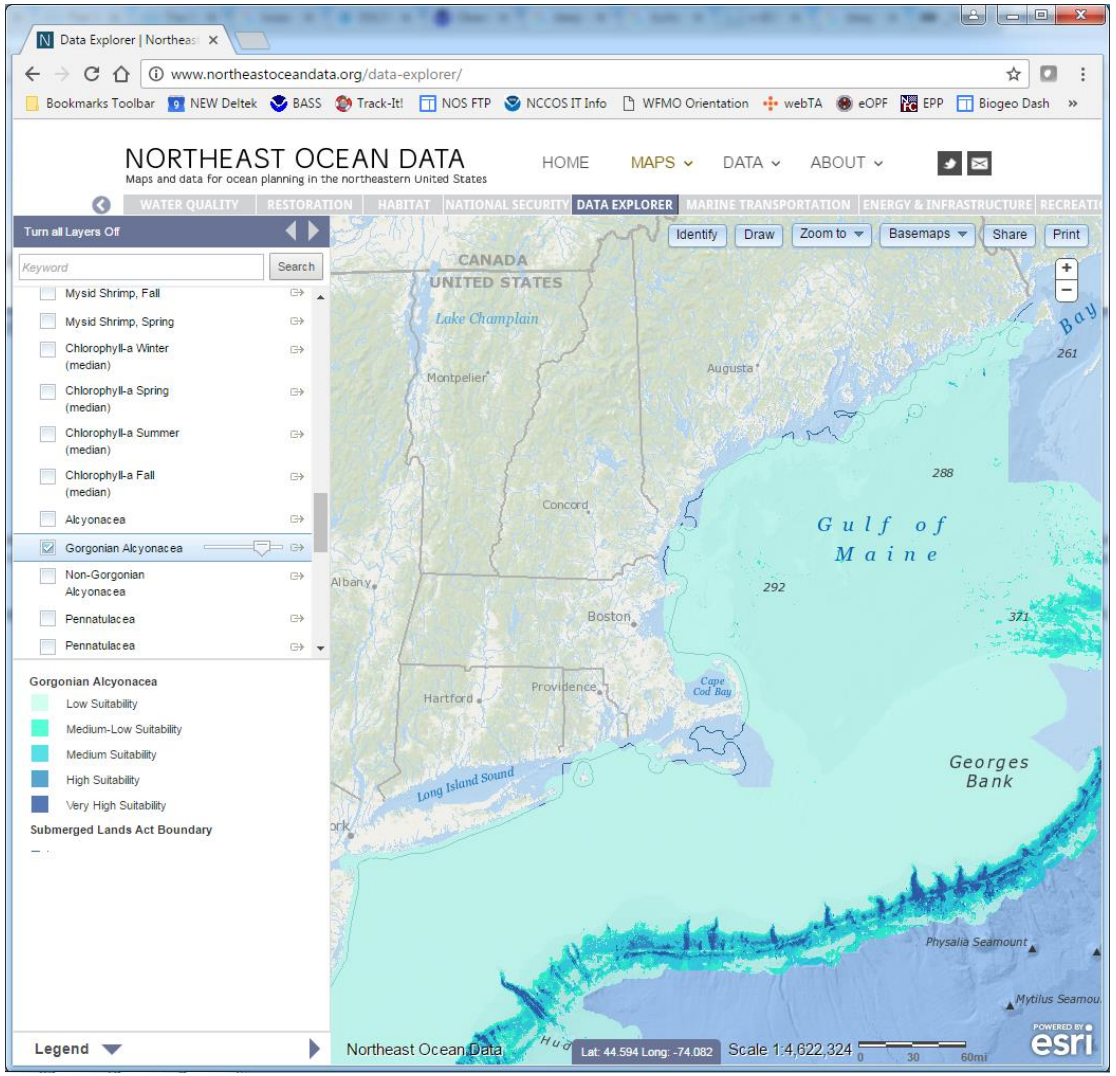
SIX STATES
- Connecticut
- Rhode Island
- Massachusetts
- New Hampshire
- Maine
- Vermont

SIX FEDERALLY RECOGNIZED TRIBES
- Aroostook Band of Micmacs
- Houlton Band of Maliseet Indians
- Mashpee Wampanoag Tribal Council
- Mohegan Indian Tribe of Connecticut
- Narragansett Indian Tribe of Rhode Island
- Wampanoag Tribe of Gay Head (Aquinnah)

NINE FEDERAL AGENCIES
- Joint Chiefs of Staff
- US Department of Agriculture
- US Department of Commerce
- US Department of Defense
- US Department of Energy
- US Department of Homeland Security
- US Department of the Interior
- US Department of Transportation
- US Environmental Protection Agency

NEW ENGLAND FISHERY MANAGEMENT COUNCIL

EX-OFFICIO MEMBERS
- New York
- Canada



NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**
National Ocean Service

Northeast and Mid-Atlantic Regional Ocean Planning

MID-ATLANTIC REGIONAL
OCEAN ACTION PLAN

[Mid-Atlantic Regional Planning Body Member Entities]

STATES

Delaware | Maryland | New Jersey | New York | Pennsylvania | Virginia

FEDERALLY RECOGNIZED TRIBES

Shinnecock Indian Nation | Pamunkey Indian Tribe

FEDERAL AGENCIES

Department of Agriculture (represented by the Natural Resources Conservation Service)

Department of Commerce (represented by the National Oceanic and Atmospheric Administration)

Department of Defense (represented by the U.S. Navy and the Joint Chiefs of Staff)

Department of Energy (represented by Energy Efficiency & Renewable Energy)

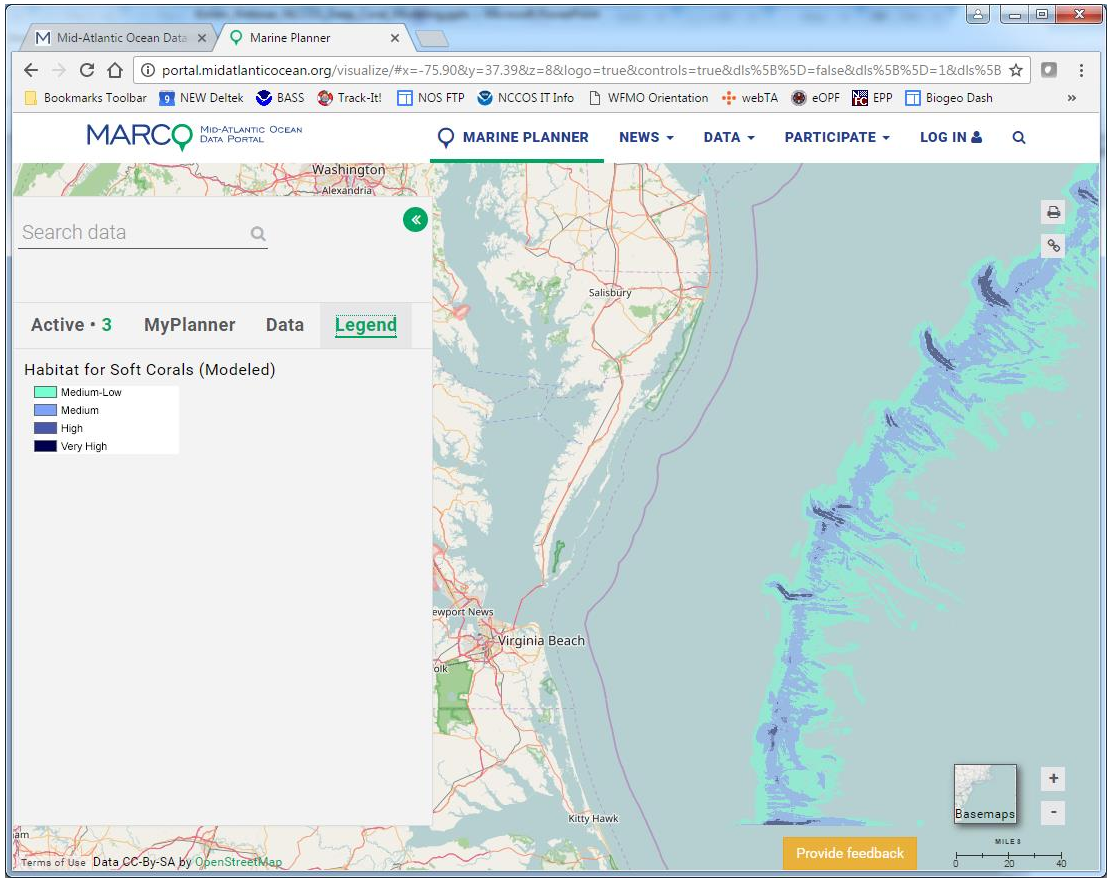
Department of Homeland Security (represented by the U.S. Coast Guard)

Department of the Interior (represented by the Bureau of Ocean Energy Management)

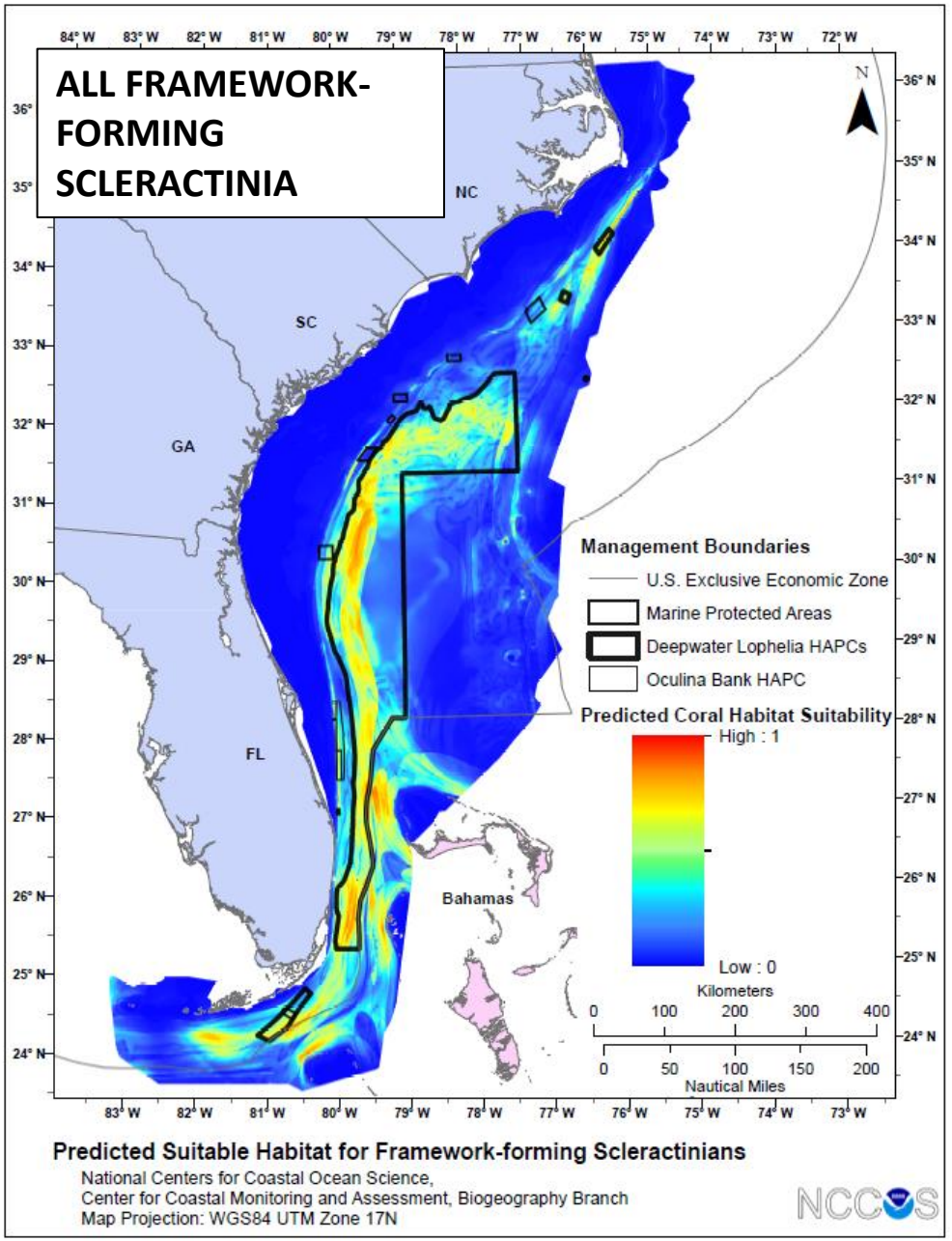
Department of Transportation (represented by the Maritime Administration)

Environmental Protection Agency

MID-ATLANTIC FISHERY MANAGEMENT COUNCIL



Southeast Deep Coral Essential Fish Habitat



Modifications to Coral Habitat Areas of Particular Concern

South Atlantic Fisheries Management Council 2012-2014

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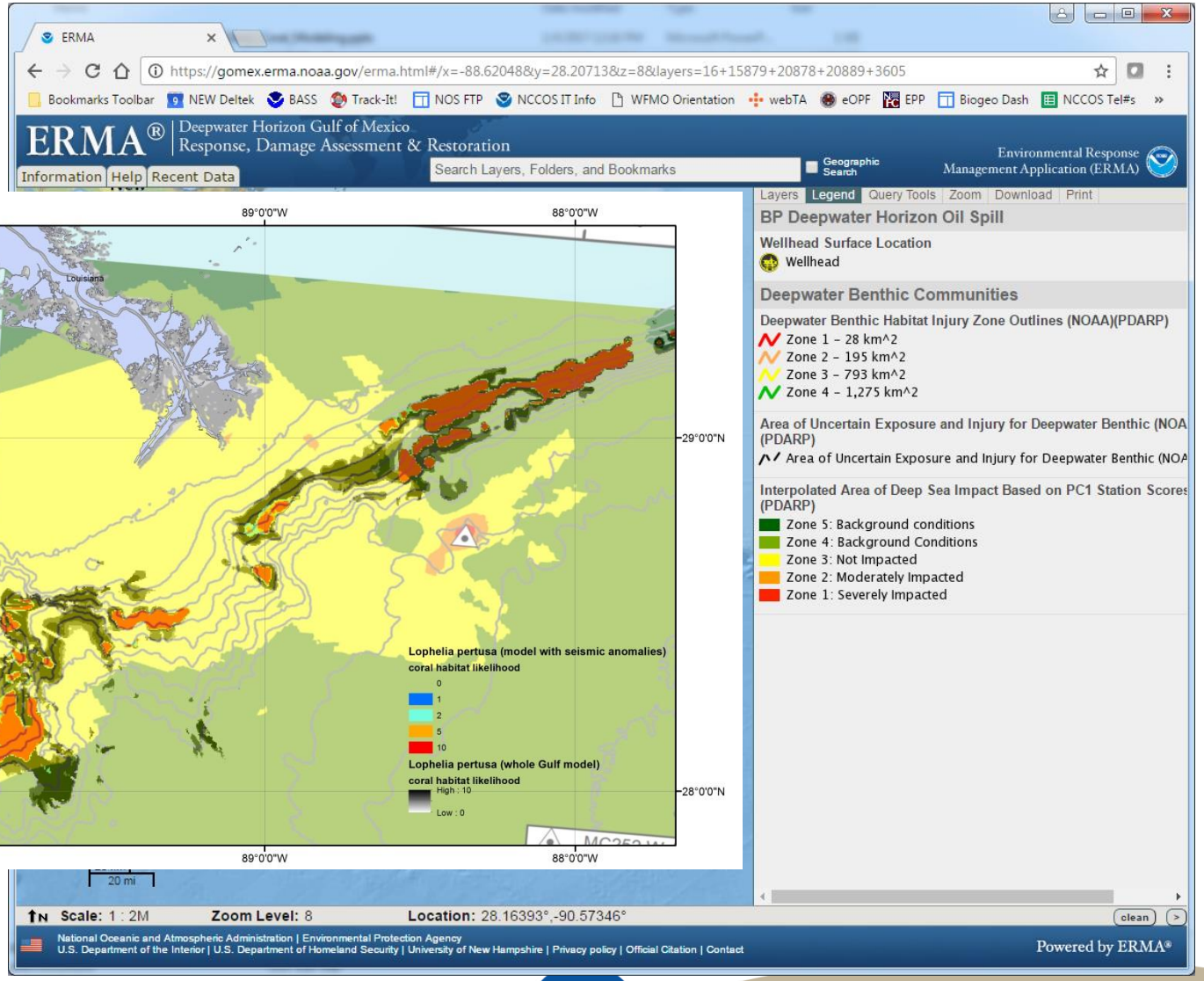
National Ocean Service

Gulf of Mexico Oil & Gas Environmental Assessment & Restoration



Hawai’i Renewable Energy & Deep-Sea Mining Planning

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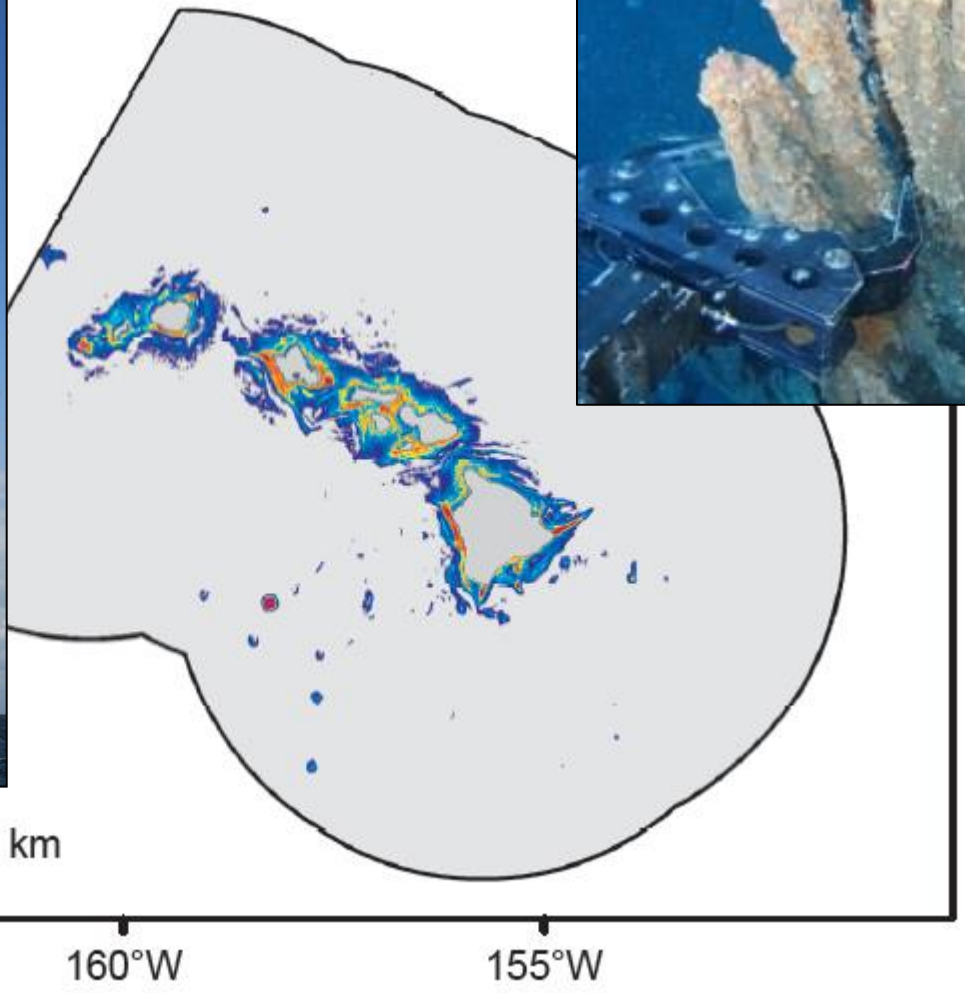
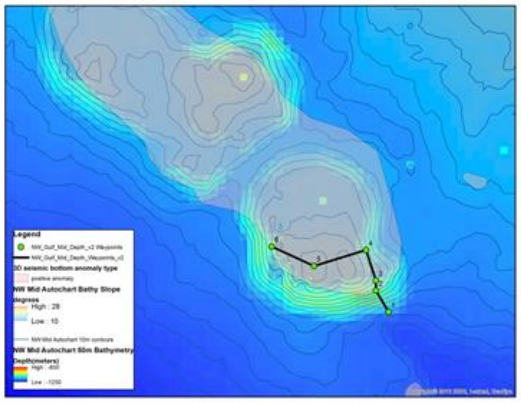


Targeting Deep Ocean Exploration

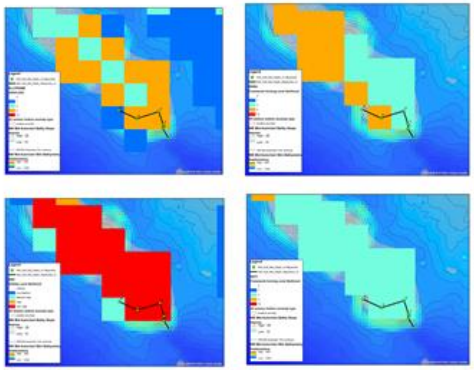
Key partner: NOAA OER – Okeanos Explorer Program

NOAA *Okeanos Explorer* Program
ROV Dive Planning Form

Map 2: Requested dive track (black line & numbered green dots), overlaid on map of 50m bathymetry (NGDC archive-Autochart), 10m depth contours, slope, and BOEM 3D seismic bottom anomalies.



Map 3: clockwise from top left: model predictions for "All Framework Forming Corals", Paramuriceidae, Isididae, and Antipatharia based on the NCCOS model for the Northwestern Gulf



Please send the completed form to Kelley.Elliott@noaa.gov and Jamie Austin (Jamie@utig.ig.utexas.edu)

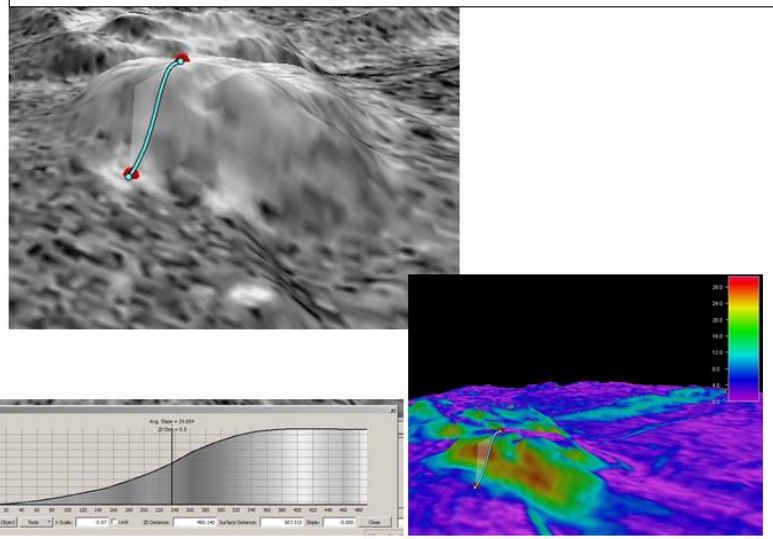
Site Name: Northwest Gulf Mid Depth (version 2)

Approximate Location: 27.07778620, -92.81612782, -1152.86 m

Dive Date (local): 2014/04/14

Site map:

Transect Line from base of 30o slope mound to top of feature overlaid on backscatter – (Top left) and overlaid on slope (bottom right). Bottom left shows the profile of the transect line.



Targeting Deep Ocean Exploration

DSCRTP Southeast Initiative 2016-2019

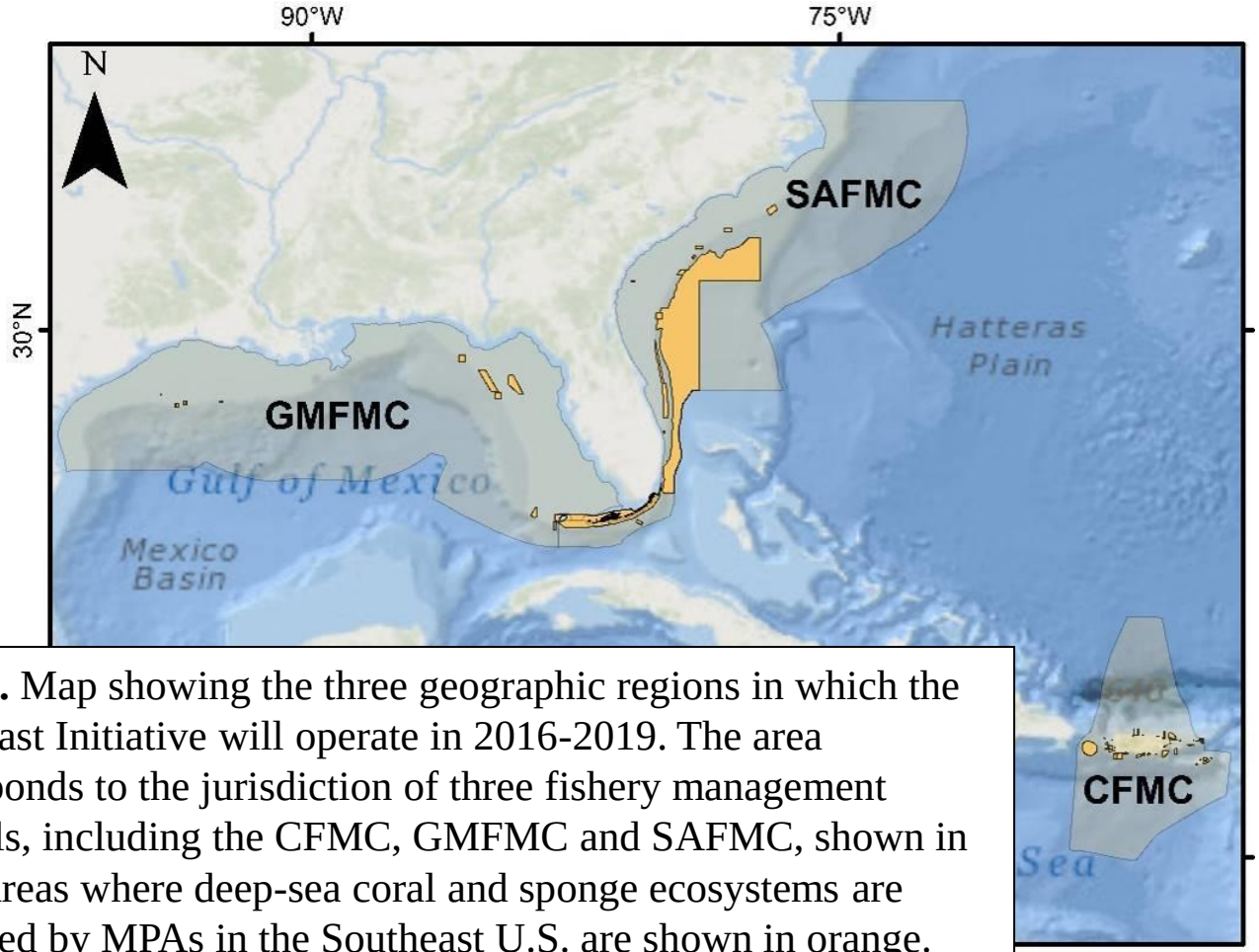


Figure. Map showing the three geographic regions in which the Southeast Initiative will operate in 2016-2019. The area corresponds to the jurisdiction of three fishery management councils, including the CFMC, GMFMC and SAFMC, shown in gray. Areas where deep-sea coral and sponge ecosystems are protected by MPAs in the Southeast U.S. are shown in orange.

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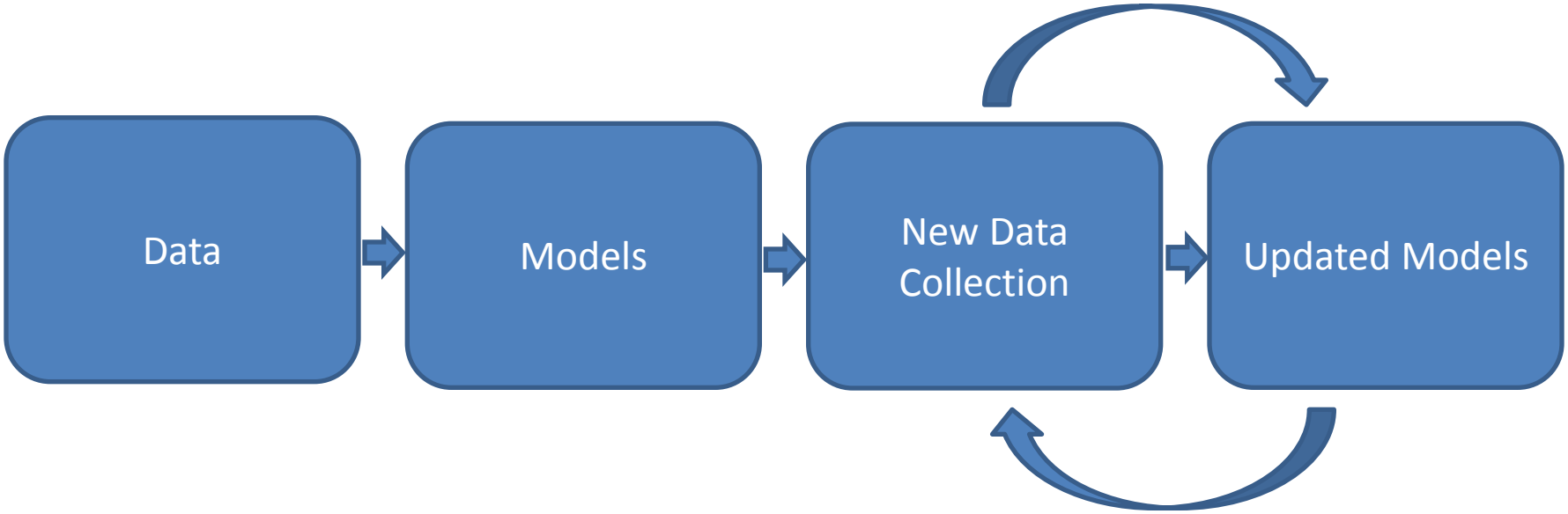
Conger eel and squat lobster in *Lophelia* reefs.
Photo Credit: S. Ross et al.

Iridogorgia Photo Credit: NOAA OER 2012

Links between Deep-Sea Coral Data, Models and Applications



Spatial Planning
Conservation Design
Environmental Impact Assessment
Hypothesis Generation

Adaptive Spatial Management
Improved Conservation Plans
Better Impact Assessments
Learning

Moving Beyond Presence-Only Models: Challenges

1. Absences not recorded
2. Accounting for spatial scale
3. Statistical framework for data integration

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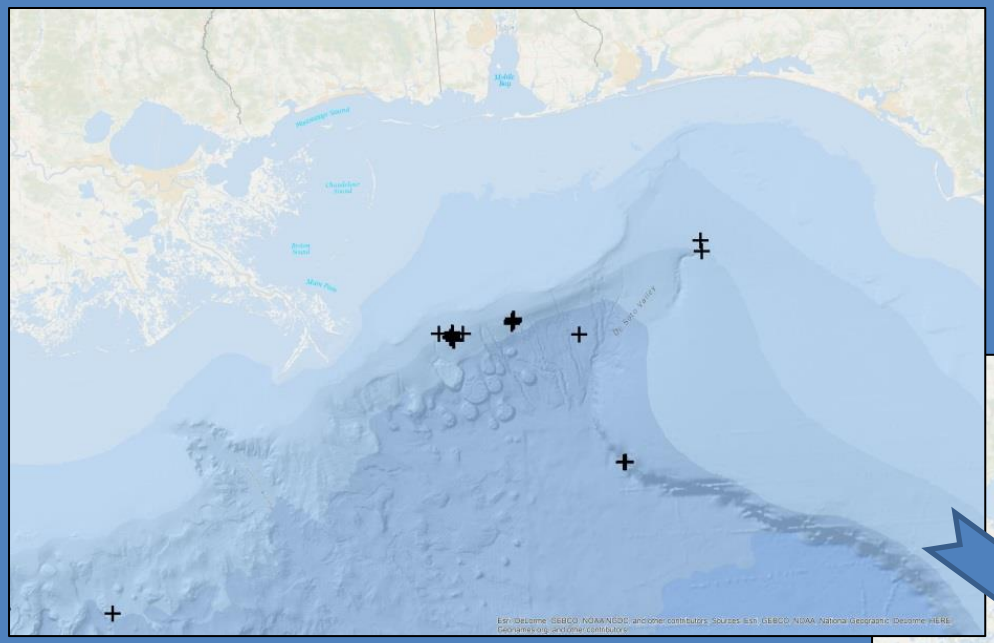
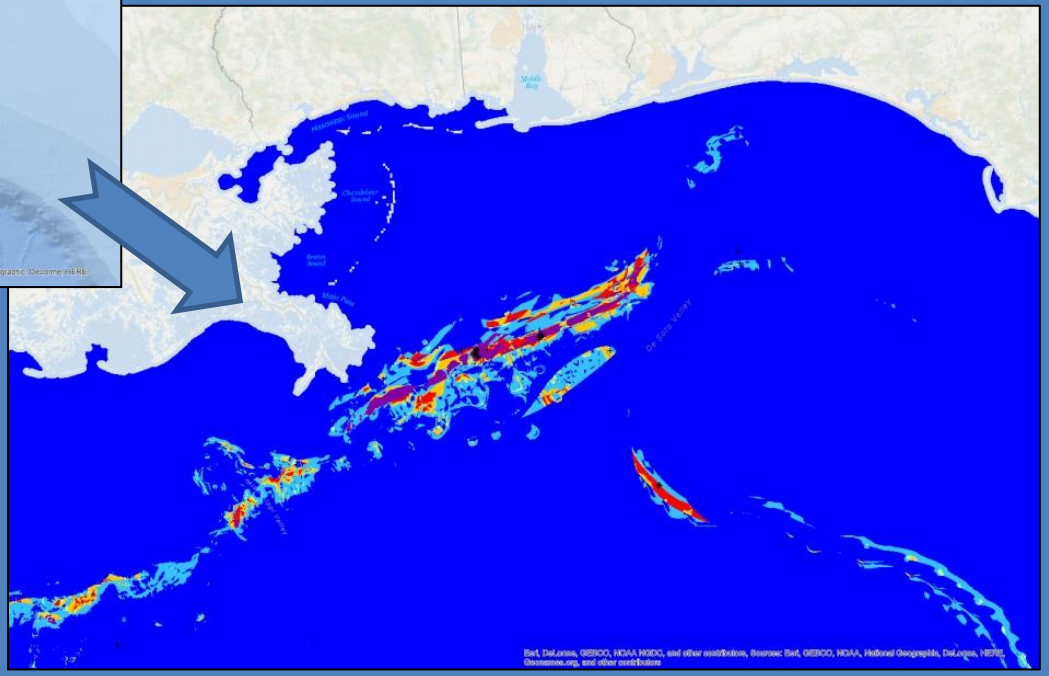
Models Are an Essential Tool for DSC Conservation & Management



Leiopathes presences

Photo credit: NOAA OER



Leiopathes presences overlaid on model

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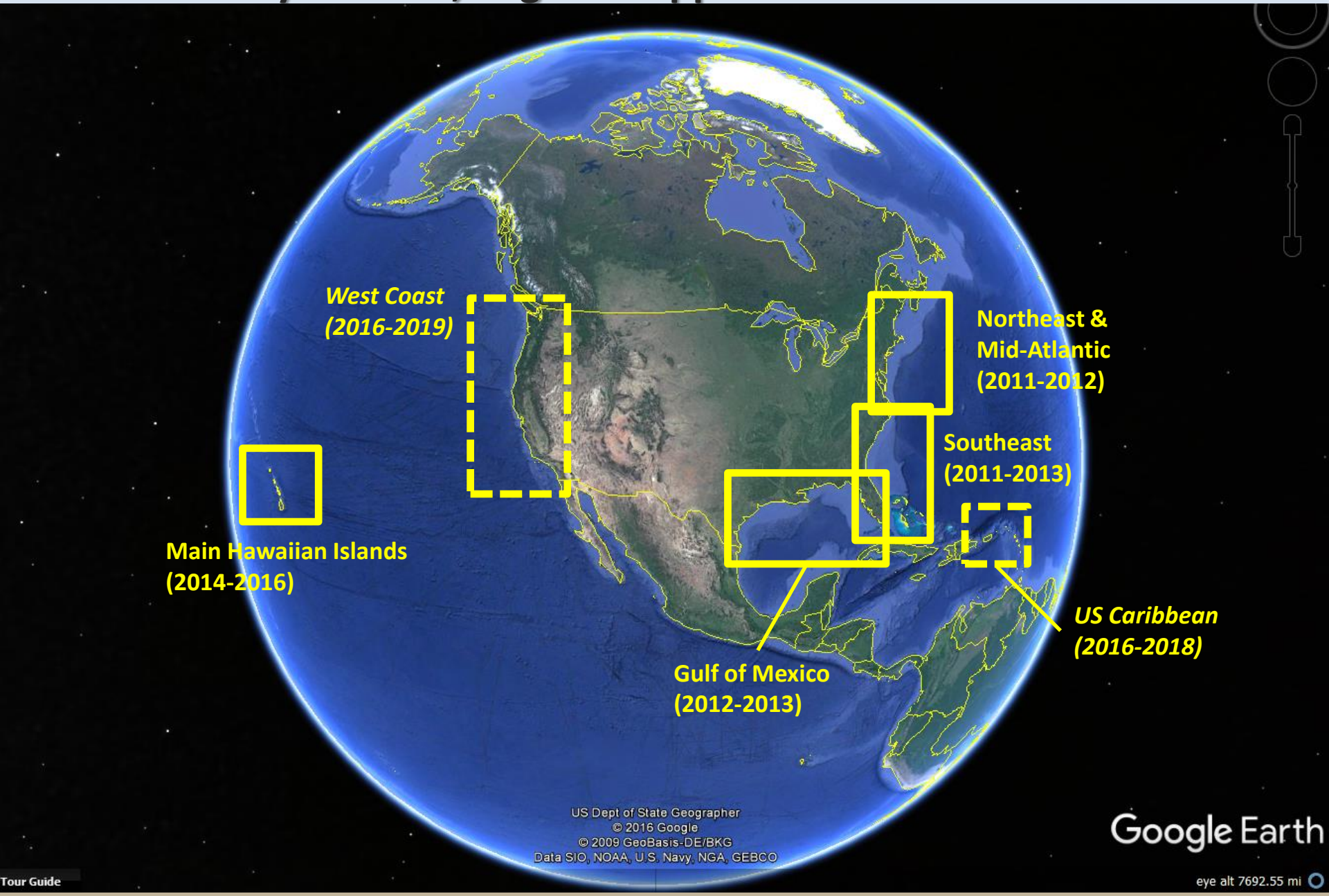
National Ocean Service

Benefits of a Systematic, Regional Approach



Acknowledgments

- NOAA NMFS Deep Sea Coral Research and Technology Program
- NOAA NMFS Fisheries Science Centers
- NOAA NMFS National Systematics Laboratory
- NOAA OAR Office of Ocean Exploration & Research
- NOAA Cooperative Institutes & numerous academic partners
- DOI Bureau of Ocean Energy Management
- DOI US Geological Survey
- Smithsonian Institution

Questions?

BRIAN P. KINLAN
Biogeography Branch
National Centers for Coastal Ocean Science (NCCOS)
NOAA National Ocean Service
Brian.Kinlan@noaa.gov